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DELIVERING THE GOODS

Summary

Public Works Technologies, Management, and Financing

CONGRESS OF THE UNITED STATES
OFFICE OF TECHNOLOGY ASSESSMENT

J952-39

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Foreword

Traffic jams and bridge lanes closed for maintenance create headaches for travelers and transportation officials, and public works directors would give their eyeteeth to find a way to solve leaking water pipe and storm water overflow problems. Such vexing difficulties are the legacies of years of neglect and underfunding for the infrastructure that provides vital public works services. In 1988, following a number of national studies calling in vain for more investment in public works infrastructure, the Senate Committee on Environment and Public Works and the House Committee on Public Works and Transportation asked OTA to identify ways to change Federal policies and programs to mobilize management, financing, and technology efforts to make public works more productive and efficient. The Senate Committee on Commerce, Science, and Transportation and the Subcommittee on Transportation of the Senate Committee on Appropriations both expressed their interest and concern by endorsing the study.

OTA identifies several immediate steps the Federal Government could take. First, new environmental standards, population shifts, and industrial changes have transformed the nature of many public works problems, and Federal programs must be refocused to fit the new circumstances. Second, if we expect to maintain our economic health, the Nation must increase its investment in public works, despite budget dilemmas. As it stands now, critical infrastructure, such as bridges, Interstate highways, sewage pipes, and water systems, are breaking down or wearing out faster than we can repair or replace them. The toll on national productivity is already substantial, and, because infrastructure investment has been declining for at least a decade, the situation is likely to get worse before it can get better.

Reauthorization of the Federal highway program is the first piece of major public works legislation to reach the top of the Federal agenda for the 102d Congress. The priorities that OTA has identified should help Congress in its deliberations on this and other transportation and environmental legislation and lead to actions that will ensure the continued vitality of our country's infrastructure.

Members of the advisory panel, workshop participants, and a host of government, industry, and private citizen reviewers for this study provided an invaluable range of perspectives and information. OTA is grateful for the substantial commitment of time and energy given so generously by each. Their participation does not necessarily represent endorsement of the contents of the report, for which OTA bears sole responsibility.

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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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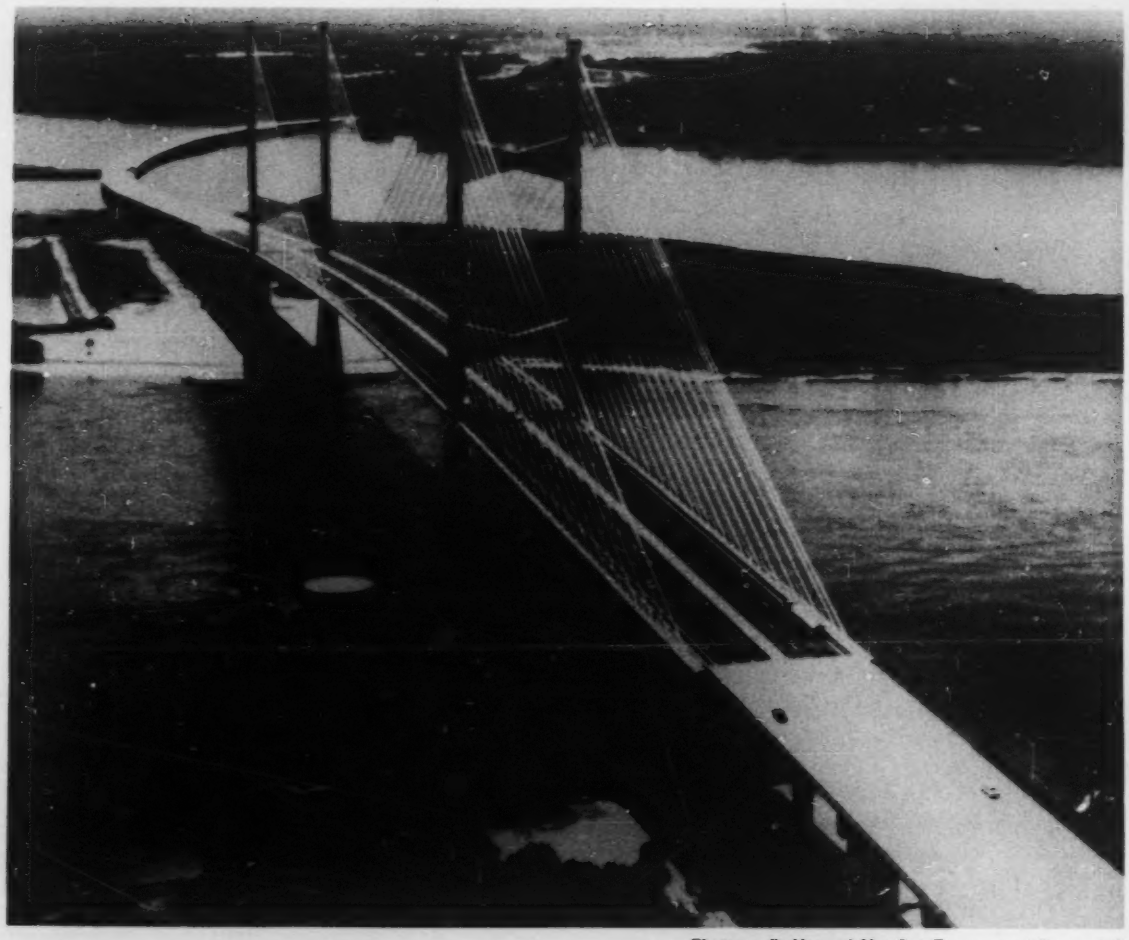

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Summary

When we try to pick out anything by itself, we find it hitched to everything else in the universe—John Muir

Smart cars and highways, high-speed trains and tiltrotor aircraft, drinking water treatment at the tap, low-flush toilets, and computer-directed sewer inspection robots—how these exotic-sounding technologies contrast with the traffic jams, potholes, sewer system overflows, and air pollution that regularly plague residents in major cities! Most of us take the services provided by public works for granted—until they malfunction at our expense. However, such complacence is foolish, considering the staggering size of our country's investment in public works infrastructure. The value of the capital stock represented in the Nation's roads, bridges, mass transportation, airports, ports, and waterways; and water supply, wastewater treatment, and solid waste disposal facilities is estimated to be about $1.4 trillion, slightly over 20 percent of the country's total public and private capital stock.[1] Federal, State, and local governments currently spend about $140 billion annually on building, operating, and maintaining these facilities.

If the infrastructure is so valuable, and technologies have such promise, why are so many public works systems across the United States outdated, inadequate, or poorly maintained? A combination of three factors is largely responsible. First, most of the basic infrastructure has been in place for at least 20 years (some is a century old) and needs either major rehabilitation or replacement. Second, shifts in population and transportation patterns have overburdened infrastructure in the major urban areas and left small, rural jurisdictions and rural States struggling to provide adequate services from shrinking economic resources. And last, but perhaps most important, Federal, State, and local governments face major budget problems.

The Federal Government has always played a key role, through financing and promoting new capital programs for public works, in spurring economic development. In 1989, Federal contributions totaled just over $24 billion (in 1982 adjusted dollars), 2.5 percent of total Federal outlays, down from about $30 billion, closer to 4 percent, at the start of the 1980s. Environmental public works programs, rail, and mass transit have borne the brunt of the cuts in Federal infrastructure support; aviation and highways have fared better (see table 1). State and local governments have increased their expenditures for public works, but not enough to make up for the drop in Federal contributions, and nowhere near enough to cope with their problems.

Economists have expressed concern that slowly ebbing investment in public infrastructure over a period of years has caused a portion of the decline in productivity growth in the United States.[2] OTA's research indicates they are right. Delays due to highway congestion in major urban regions already take a toll of more than an estimated $30 billion annually (see table 2), almost one-half of the roughly $65 billion total spent by Federal, State, and

Table 1—Federal Infrastructure Expenditures, 1980 and 1989 (in millions of 1982 adjusted dollars)

	1980	1989
Total	$29,863	$23,609
Transportation infrastructure:		
Highways	10,584	11,392
Mass transit	3,732	2,838
Rail	3,531	483[a]
Aviation	4,334	5,378
Ports, harbors, waterways	1,365	1,137
Environmental infrastructure:		
Water supply	1,017	284[b]
Wastewater	5,300	2,097

[a]Drop in expenditure reflects sale of Conrail.
[b]Low spending figures for water supply in 1989 reflect repayments of Farmer's Home Administration water supply loans.

SOURCE: Office of Technology Assessment, 1991. Based on preliminary Congressional Budget Office estimates, Office of Management and Budget historical data, and U.S. Army Corps of Engineers estimates.

[1]OTA estimates, based on Alicia H. Munnell, "Why Has Productivity Growth Declined? Productivity and Public Investment," *New England Economic Review*, January/February 1990, p. 14.

[2]Ibid.

Table 2—Traffic Congestion Increases in 15 Major Cities

Cities	Congestion index[a] (1987)	Percent change (1982-87)	Annual cost of congestion: Total[b] (in billions of dollars)	Annual cost of congestion: Per capita (in dollars)
Los Angeles	1.47	20%	$7.9	$730
San Francisco-Oakland	1.31	29	2.4	670
Washington, DC	1.25	31	2.2	740
Phoenix	1.23	6	0.9	510
Houston	1.19	1	1.5	550
Atlanta	1.16	30	1.1	650
Seattle	1.14	20	0.9	580
New York	1.11	4	6.8	430
Chicago	1.11	11	2.5	340
Detroit	1.10	–2	1.9	480
San Diego	1.08	38	0.6	280
Philadelphia	1.06	17	2.1	520
Dallas	1.03	22	1.0	530
Minneapolis-St. Paul	0.97	24	0.5	240
Milwaukee	0.94	10	0.2	190

[a]The congestion index is a weighted measure of urban mobility levels, and cities with values greater than 1.0 have congestion problems. Roads carrying more than 13,000 vehicles per freeway lane per day or 5,000 vehicles per arterial lane per day are considered congested.
[b]Congestion cost is the estimated cost of travel delay, excess fuel consumed, and higher insurance premiums paid by residents of large, congested urban areas.

SOURCE: Office of Technology Assessment, based on Texas Transportation Institute, "Roadway Congestion in Major Urban Areas, 1982 to 1987," Research Report 1131-2, 1989.

local governments for highways in 1987[3] (the last year of the congestion study), and overcrowding on the roads has increased every year since. However, reversing the downward trend in public works outlays will not be easy. It will require fundamental changes in governmental policies and spending priorities, and these do not happen quickly.

The 1990s thus loom as a pivotal decade for public works. Squeezed by demands for every conceivable type of public service, State and local officials have postponed routine maintenance and rehabilitation of vital infrastructure systems for years. For example, lining the aged water supply pipes of a major city could have prevented a leakage rate of almost 40 percent of treated drinking water over the past several decades, more than enough to make up shortages during dry spells. The city, however, has only recently allocated money for the project, for decades finding expenditures for police, schools, and caring for elderly and homeless more pressing.

But many factors other than fiscal woes keep new management solutions and technologies that could bring greater productivity and efficiency from being integrated quickly into public works. Major population shifts and industrial and technology changes have occurred over the past 15 years (see box A), creating new public works needs far faster than the slow movements in corresponding public attitudes and government policies and institutions. Because public works programs are easy targets for budget cuts and wage scales are low, officials are faced by critical shortages of expert management and technical personnel to plan for, implement, and manage

Photo credit: American Society of Civil Engineers

Delays caused by highway congestion cost the public at least $30 billion annually.

[3]U.S. Department of Transportation, Federal Highway Administration, "Selected Highway Statistics and Charts 1989," November 1990, p. 19. Federal experts unofficially state that the costs of congestion may now equal or exceed total highway expenditures, which were $72 billion in 1989. Anthony R. Kane, associate administrator, Engineering and Program Development, Federal Highway Administration, personal communication, Jan. 28, 1991.

new technologies. Liability concerns in both the public and private sectors about the consequences of a new program or equipment that does not perform well are further barriers to new technologies.

Even if such obstacles were to be overcome, reaching consensus on the best approach and choice among new technologies is a Herculean task. While most people agree on the importance of protecting the environment and the quality of life, they do not agree on how to do this in a way that nourishes rather than saps economic vitality. Ironies resulting from attempts to address these divisive concerns can be seen across the country. Although the Nation has been a world leader in developing and implementing environmental protection policies, residents of many of the largest cities confront air quality problems tied to traffic congestion that threaten the quality of life in their communities. Los Angeles, for instance, installed new computer-managed traffic signal equipment, improving traffic flow by 10 to 20 percent,[7] at significantly lower cost than constructing new highway lanes. But the city still has the worst traffic congestion and air quality in the country, and public debate continues to rage over what to do next. Californians (and residents of other States with large, urbanized areas) must reach agreement on land-use requirements, travel alternatives, and funding for new transportation options, and will probably have to accept major changes in priorities and lifestyles to resolve environmental concerns.

Finding solutions to such complex problems is hard enough, even when known technologies can do the job, but choosing among new technologies (that might do better) is even more difficult, because so little is known about how they will actually perform. Only the Federal Government has the resources to support large-scale, applied research and development (R&D) programs for public works, and these have been cut drastically or neglected in recent years. Now, no significant, comprehensive, Federal technology research and support programs exist for State and local governments seeking advice about solutions to long-range problems. Until appropriate new technology choices are obvious, governments will do well to give priority to upgrading and rehabilitating existing facilities to keep them functioning as efficiently and productively as possible, while the search for a better answer continues.

Although budget dilemmas make dramatic increases in Federal spending for public works unlikely, if more investment in certain crucial areas is not ensured soon, the negative impacts on transportation efficiency, industrial productivity, and national competitiveness will cost the country dearly. **OTA concludes that changes to Federal program management, investment policies, and R&D are needed now, if the opportunities that technology offers for public works are to be fully utilized. Immediate attention should also be given to developing programs to determine the most promising new technologies for public works and long-term strategies for implementing them.** In brief, the most important steps for Congress to take now to make public works more productive and efficient are to:

- revise Federal investment policies and program management to address today's concerns by making current systems more productive through available technologies, by maintaining existing infrastructure, and by planning and budgeting for future needs, using a comprehensive systems approach to both transportation and environmental problems;
- increase Federal public works funding selectively and use Federal programs to leverage State and local spending, so as to boost the total annual national investment in public works by up to 20 percent initially and to ensure regular, subsequent, annual increases;[8] and
- collect information that will enable the government to refocus support for short-term R&D to target applied technologies that will improve the condition, extend the life, and increase the capacity of existing public infrastructure; then, using the data as a base, develop and implement long-term systems R&D programs to address future needs.

Recognizing that Federal policies for public works urgently need review, Congress asked OTA to assess infrastructure problems across the country and to pay special attention to the problems of small systems and the opportunities for privatization and

[7]U.S. Congress, Office of Technology Assessment, "Advanced Vehicle/Highway Systems and Urban Traffic Problems," staff paper of the Science, Education, and Transportation Program, September 1989, p. i.

[8]OTA's estimates of the potential impacts of different levels of Federal spending for public works may be found in table 6.

Box A—Trends Affecting Public Works Infrastructure[1]

Demographic Trends

The U.S. population is projected to increase by 32 million people between 1990 and 2010, with middle-age categories showing the most growth. The South and West accounted for 90 percent of population growth in the 1980s. These regions will continue to expand the fastest, and California and Florida will grow the most. Population in the Midwest is projected to decline. Almost all new population growth is expected to occur in the suburbs of major metropolitan areas, where almost two-thirds of the metropolitan population already lives. One-quarter of the population now lives in the seven largest metropolitan areas. Of new metropolitan area jobs, three-quarters will be in the suburbs.

Implications for Public Works

Strong demand for transportation services by the growing numbers of middle-aged baby boomers and growth in vehicles per household will cause travel to outpace both population and economic growth, and increase traffic congestion, particularly in and between suburbs and in newer cities built without consideration of mass transit. Demand will rise for mass transit and more efficient intercity travel. Already deep, the divide will widen between service needs and fiscal capabilities of urban and rural jurisdictions. Environmental dilemmas will intensify, particularly air quality and waste disposal problems in metropolitan areas and water supply issues in Florida and the Southwest.

Economic Trends

The shift from goods production to service delivery will continue, with production employment dropping 16 percent by 2000 and service employment increasing 13 percent. The Nation's labor force growth rate will slow, primarily because the supply of younger workers is shrinking. More flexible manufacturing technologies will encourage decentralized manufacturing and just-in-time delivery. Demand for transportation of industrial raw materials will drop, but overall transportation demand will expand, especially for lightweight, high-value products. This will put a premium on speed and reliability—values likely to favor air and truck transport, although rail can be competitive in certain corridors. Changes in communications and transportation will accelerate economic globalization, encouraging growth around selected deep-water ports and major airports.

Implications for Public Works

Highway travel is expected to double over the next 30 years, putting an enormous burden on existing roadways. To compensate for the adverse economic impact of slower labor force growth, both public and private sectors may invest more heavily in transportation to improve the speed and efficiency of travel and transport. Economic

[1]Trends and analysis in this box are based on material in U.S. Department of Transportation, *National Transportation Strategic Planning Study* (Washington, DC: March 1990), chs. 1-5, and OTA research.

public-private partnerships. Building on the conclusions reached in OTA's special report to Congress on State and local public works,[6] this report examines the public works decisionmaking framework and suggests changes in management, financing, and technology that could lead to both robust economic development and environmentally sound transportation and environmental public works systems. This chapter identifies short-term tactical options and long-term strategic goals for Congress to consider, and points to ways to set priorities for more productive and efficient public works services. Additional background and supporting details and findings appear in chapters 2 to 6 of the full report.

Intergovernmental Framework

Public works provide environmental and health-related services and underpin productive transportation networks, and they must function efficiently or economic vitality and the quality of life will decline. Strong, mutually supportive intergovernmental partnerships and continuous interchange with industry and other concerned groups are essential to shaping appropriate policies and programs. The Federal form of government has long served the country well, because it provides multiple opportunities for debate and discussion before decisions are taken. However, the present intricately complicated intergovernmen-

[6]U.S. Congress, Office of Technology Assessment, *Rebuilding the Foundations: A Special Report on State and Local Public Works Financing and Management*, OTA-SET-447 (Washington, DC: U.S. Government Printing Office, March 1990).

globalization means west coast ports and intermodal connections will become increasingly important as Pacific trade grows. The need to expand capacity and improve intermodal connections will intensify around international and domestic airports.

Environmental Trends

The economic and political importance of environmental preservation and restoration issues will accelerate. While pollution from heavy industry may decrease as a result of economic restructuring, the challenge to control nonpoint sources of air and water pollution will grow.

Implications for Public Works

Communities will continue to invest heavily in air and water pollution control and drinking water system improvements and in complying with Federal and State standards. Collection and disposal of solid waste and facility siting are becoming dominant issues. Environmental service needs already place a heavy burden on most local budgets, and as more regulations are implemented the fiscal burden is very likely to worsen (see table A-1). As the link between transportation and the environment is better understood, the environmental impacts of all proposed public works projects will be scrutinized carefully by public and private groups. Air quality issues are likely to be major determinants of public policy on transportation and land use. If worst-case projections are correct, global warming and rising of water levels will affect infrastructure in coastal areas.

Energy Use Trends

Transportation accounts for approximately two-thirds of all petroleum use, an amount that equals imports, and of that over 70 percent is consumed by highway transport. Substantial increases in world energy and petroleum demand and uncertainty of supply are expected to lead to much higher energy prices. Fuel efficiency of new cars doubled between 1973 and 1988, and many see the potential for further improvement.

Implications for Public Works

Despite rising petroleum costs, major modal shifts are unlikely, although the cost-effectiveness of transit and other nonhighway transport will increase. Higher gas prices may limit discretionary trips and over the long run encourage more compact development, but unless costs are radically higher, highway travel demand will continue to increase.

Table A—Public Works Cited as Having Major Cost Impacts on Cities

Public works requirement	Percent of cities citing impacts
Solid waste disposal	75%
Traffic improvements	66
Sewage collection and treatment	58
Drinking water supply and treatment	42

SOURCE: National League of Cities, *City Fiscal Conditions in 1990* (Washington, DC: July 1990).

tal framework (see table 3) frequently overtaxes the decisionmaking process and impedes new policy development in public works as effectively as a major accident stalls rush hour traffic.

A word about OTA's approach to analyzing the broad scope of public works infrastructure is appropriate before beginning more detailed discussion. At every governmental level, environmental public works are managed and financed differently from transportation programs and operations. Long-standing and disparate methods of funding and Federal/State/local institutional relationships for each type of service are major roadblocks to integrating environmental with transportation infrastructure management and programs. Moreover, successful improvements seem more likely in the foreseeable future, with continued separation. Consequently OTA addressed environmental and transportation public works separately and developed policy options for each. Over the longer term, incorporating both systems within a comprehensive Federal infrastructure policy could be useful, but attempting such a step now would involve too many changes to existing conditions.

Federal Decisionmakers

The constitutional separation of powers requires that the executive branch, Congress, and the courts share responsibility for developing and implementing Federal policy. For example, to ensure that the U.S. Department of Transportation (DOT) and the U.S. Environmental Protection Agency (EPA) carry out its intent, Congress may write detailed requirements and standards into legislation. This very specificity may ensure that complex standards find their way into the courts. (Further information about these Federal checks and balances of power as they affect public works will be found in chapter 2 of the

Table 3—Public Works Management

Players	Public works role
• Congress	Congress authorizes programs, appropriates funds, and sets regulations. Multiple committee and subcommittee functions hamper comprehensive policymaking, and may delay change.
• Executive agencies controlling public works construction and regulations: EPA, DOT, Army Corps of Engineers, and Bureau of Reclamation	Agencies assign, construct, regulate, and finance public works facilities. Modal and media-based administrative structure hampers integrating programs; implementation of regulations dominates EPA activities.
• Other executive agencies: Treasury	Treasury sets revenue policy, including criteria for arbitrage and tax exempt bonds, which affects cost of raising capital for some public works projects.
OMB	OMB reviews agency budgets and regulations and has a strong influence on regulatory and spending policies.
• The courts	Courts interpret and enforce legislation and regulations pertaining to public works programs. Judges set program requirements and standards. Litigation lengthens rulemaking process and implementation, but resolves disputes.
• State government	States fund and construct public works and set and enforce regulations. Activities vary by State according to philosophy and fiscal capability. States play a major role in highways and enforcing environmental regulations, and are enlarging their role in other public works areas.
• Local government	Local governments design, construct, operate and fund public works, set local policy, and deliver service within Federal and State program regulations. They have full responsibility for funding and operating most environmental programs. States limit fiscal options of local governments.
• Private sector	Private firms are major users of public works. Also, they construct (e.g., highways and treatment plants) and operate facilities (e.g., drinking water and solid waste disposal facilities).
• Interest groups	Groups influence legislative and executive branch policies through lobbying, and pursue specific objectives through litigation.
• The public	The public creates service demand, but their resistance to taxes and service charges limits public works spending and allows maintenance and improvement to be deferred. Individual lifestyle preferences determine land-use and transportation patterns.

KEY: EPA = U.S. Environmental Protection Agency; DOT = Department of Transportation; OMB = Office of Management and Budget.
SOURCE: Office of Technology Assessment, 1991.

full report.) Executive branch management is critical in shaping the emphases of Federal regulatory programs, which in turn play a major role in affecting State and local approaches.

Executive Branch

Executive branch responsibility for public works is shared by a major department (DOT), an important independent agency (EPA), and parts of three other Cabinet departments. These are the Department of Defense (DoD), through the U.S. Army Corps of Engineers, which is responsible for flood control, harbors, and inland waterways; the Department of the Interior, through the Bureau of Reclamation, which has built a number of dams, mostly for power generation, but some of which supply water; and the Department of Agriculture, which includes the Soil Conservation Service, whose water programs affect both water supply and wastewater treatment.

The Office of Management and Budget (OMB) uses its authority to modify the budget and regulatory proposals of executive departments, a power it has used extensively to hold down spending for public works in recent years. Enormous departmental effort must be expended and extraordinary congressional unity must exist to alter the effects of OMB review.

Congress

Congress is a key player in public works decisions, with almost one-half of its 304 committees and subcommittees having jurisdiction over some aspect of public works. This widespread oversight authority provides fertile soil for intercommittee conflicts, discourages good communication between committees on common issues, and enables executive branch agencies and industry interest groups to play committees off against each other. An interest group that has been unsuccessful in making its case for a special cause to one authorizing committee, for example, can lobby another committee with related responsibilities or go directly to a friendly member in the hope of having a special clause inserted into

an appropriations bill after the authorization process is over. "It's done all the time."[7]

The Courts

The courts are the final participants in the Federal policymaking arena. Their impact may be gauged by noting that about 80 percent (see chapter 2 of the full report) of EPA's standards and requirements go through litigation before becoming effective. Thus the courts' decisions balance private property and individual rights against public health and safety in areas of great scientific uncertainty.

States

Driven by the slump in Federal financing and stagnation in Federal management and by the pressing needs of local communities, many States have developed their own public works strategies. These include regulatory and land-use management controls as well as funding partnerships with local governments. For example, California has moved to control the environmental consequences of explosive growth, enacting State air quality requirements more stringent than Federal standards. New Jersey and Washington State, among others, have created State support programs to help local jurisdictions fund public works improvements (see boxes 2-A and 2-B in chapter 2 of the full report). Florida has enacted a requirement that local jurisdictions develop long-range land-use plans tied to capital budgets and regional and State plans. Oregon has developed land-use guidelines encouraging high-density housing and development along local mass transit corridors. Other States must follow their lead before long, for most have numerous local jurisdictions with the same critical infrastructure concerns.

Local Governments

Responsibility for managing, operating, and maintaining over 70 percent of all public works facilities and services is borne by the Nation's 83,000 local governments. Each worries about funding schools, jails, and the aging and homeless as well as potholes, collapsing bridges, leaking water mains, stormwater-caused sewer overflows, traffic gridlock, siting a new landfill, or expanding the airport according to the jurisdiction's geographic location, population, economy, natural resources, and a host of other factors. Most of the fiscal and political tools that local officials may use to address these problems are determined by the States.[8] Since the bulk of Federal financial aid goes to States, local officials, who must face angry constituents directly, often feel they are being held responsible for policies, service failures, and other events that are outside their control.

Transportation arteries and pollution do not stop at political boundaries, and despite their power over local jurisdictions, no State, not even large and relatively prosperous California, can solve all its public works problems alone. **OTA concludes that the interlocking nature of Federal, State, and local responsibilities for public works services makes a compelling case for strong Federal leadership. It is time for the Federal Government to acknowledge the broad impacts of its role in public works and to work aggressively to create a policy framework that addresses current problems and shapes the future.**

Federal Public Works Management

At its best, the system of Federal checks and balances ensures thoughtful, comprehensive actions. At its worst, it can result in contradictory policies and stalemate. Federal public works management provides examples of both the best and the worst; however this document focuses on the latter to indicate where change is needed most. Although comprehensive reviews of transportation and environmental issues preceded legislation creating the agencies, few substantive alterations have been made to the management framework of either DOT or EPA since the agencies were formed.

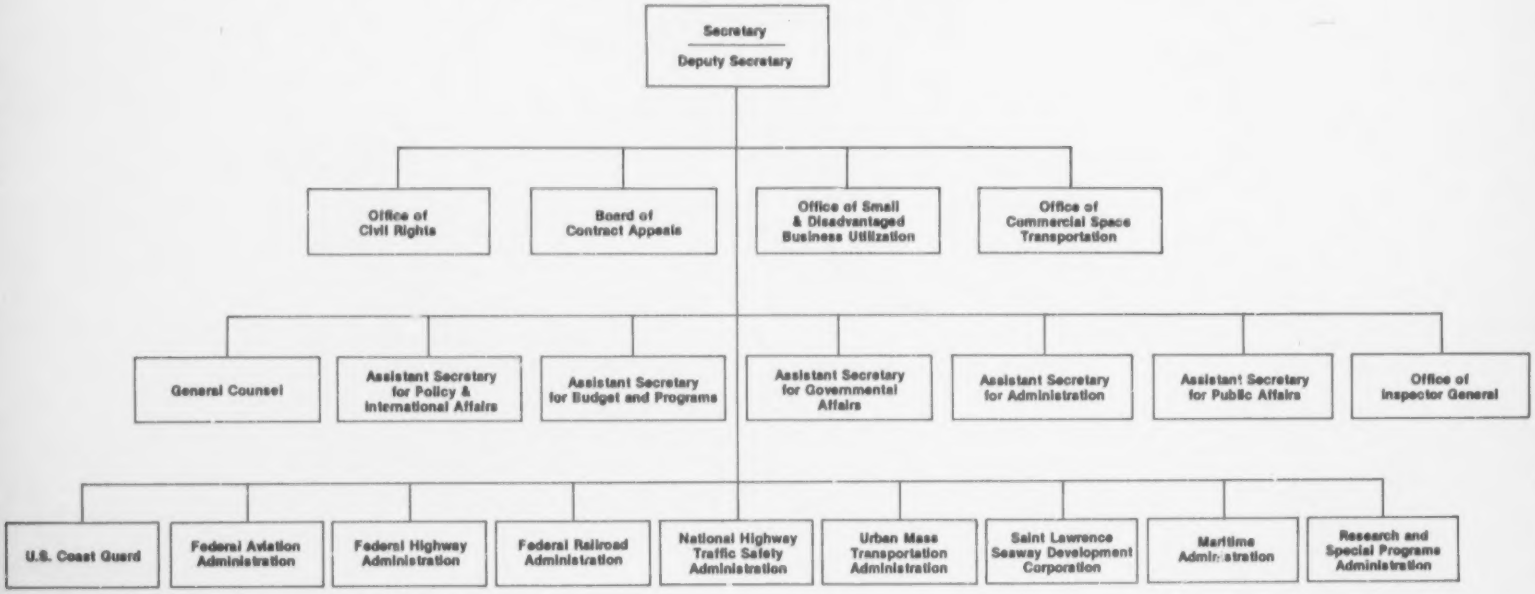
Transportation

Legislation creating DOT in 1966 established independent administrations for each transportation mode, a departmental structure that remains unchanged (see figure 1). Although virtually all of DOT's offices have some impact on public works, those with direct responsibility include the Federal Aviation Administration (FAA), the Federal Highway Administration (FHWA), the Federal Railroad Administration (FRA), the Urban Mass Transportation Administration (UMTA), and the Maritime Administration (MARAD). FHWA, FRA, and

[7]Michael Uremovich, vice president, Marketing, American President Companies, personal communication, Apr. 18, 1990.

[8]For more detailed information, see Office of Technology Assessment, op. cit., footnote 6, chs. 3 and 4.

Figure 1 — U.S. Department of Transportation


Secretary
Deputy Secretary
Office of Civil Rights
Board of Contract Appeals
Office of Small & Disadvantaged Business Utilization
Office of Commercial Space Transportation
General Counsel
Assistant Secretary for Policy & International Affairs
Assistant Secretary for Budget and Programs
Assistant Secretary for Governmental Affairs
Assistant Secretary for Administration
Assistant Secretary for Public Affairs
Office of Inspector General
U.S. Coast Guard
Federal Aviation Administration
Federal Highway Administration
Federal Railroad Administration
National Highway Traffic Safety Administration
Urban Mass Transportation Administration
Saint Lawrence Seaway Development Corporation
Maritime Administration
Research and Special Programs Administration

SOURCE: U.S. Department of Transportation, 1990.

UMTA collect data, set standards, and administer grant programs for highways, railroads, and mass transit, respectively, but have no operating responsibilities. Unique among the modal agencies, FAA regulates, manages, and operates the air traffic control system, the basic electronic infrastructure for the aviation right-of-way. MARAD is primarily concerned with the commercial aspects of ocean ports and the shipbuilding industry.

The Secretary of Transportation and his office were given responsibility for coordinating and managing the modal administrations to create a multimodal, national transportation system. However, no deputy or assistant secretary position was created to support a systems management approach, and the authority given to the modal administrators has effectively prevented every secretary to date from carrying out this charge.

In any case, DOT management of a fully multimodal system is impossible, because responsibility for the harbor and inland waterway infrastructure system rests with the Corps of Engineers. The Corps built and continues to operate and maintain the Nation's waterways and to maintain the ports. In these respects, management of the infrastructure for waterborne commerce is largely Federal.

Systems Management

Industry shippers moving goods from factory or farm to market need fast, smooth trips, while travelers of all types want safe, easy journeys. Yet traffic jams on urban roadways, often made worse by maintenance projects, cause hours of frustration and costly delay, and have become major contributors to air pollution problems. Important segments of the Nation's transportation system are overcrowded or worn out (sometimes both) and need renewal. Yet no Federal programs collect information relevant to or target intermodal system improvements that would make modal transfers faster and easier for either people or freight.

Finding ways to increase system capacity and handle greater demand without constructing new rights-of-way poses enormous challenges. New technologies can marginally increase the capacity of infrastructure, but they are often expensive and eventually reach structural limits. A systems management approach that makes full use of all modes and encourages carrying the same volume of passengers or cargo on fewer vehicles could address congestion, air quality, and energy use problems.

Intermodal Transport

DOT agencies still manage each mode as a separate, independent system, rather than a contributor to an integrated system that has complex intermodal connections in large, metropolitan areas. The steps taken by Secretary Samuel K. Skinner in early 1990 to develop a national transportation strategy and improve systems management by focusing on intercity movements and the impacts of economic, social, and environmental factors on transport are moves in the right direction.[9] However, the Department has missed out almost entirely on the major industry shift to multimodal transport, which requires intermodal transfers. DOT has no data collection or management mechanisms in place to use in analyzing or resolving the resulting issues—such as that of overweight maritime containers, which cause severe highway damage when transferred to trucks.

While recognizing that reorganizations often do not change longstanding attitudes and behavior, **OTA concludes that unless steps are taken to institutionalize an integrated, multimodal approach within DOT, the existing strongly segmented modal structure will continue to prevail.** One way to effect change would be to create surface transportation programs that support intercity passenger, urban, and freight transportation, and connections to ports and airports. **Over the longer term, DOT could be restructured in divisions by broad mode—aviation, surface, and water transportation—or by function, such as metropolitan passenger and intercity freight transportation. Separating any of the current modal responsibilities from DOT would be counterproductive to long-term national transportation policy goals.** Reforming congressional oversight, by consolidating responsibility for transportation authorization under fewer committees, could support a restructured DOT.

One way to integrate management of water transportation into the national system would be to shift civilian water transportation authority from the Corps of Engineers to DOT, as was originally envisioned when DOT was created. The

[9]U.S. Department of Transportation, *Moving America: New Directions, New Opportunities* (Washington, DC: February 1990).

rationale that the system is necessary for defense purposes is no longer any more applicable to waterways than to aviation. Consolidating the water-related agencies already in DOT would also make good management sense.

The Corps of Engineers: Time for a Change

As its defense-related responsibilities dwindle, the role of the Army Corps of Engineers deserves a fresh look. The Corps has a vast reservoir of technical expertise and research and engineering capabilities that could supplement other Federal resources, for both environmental and transportation public works. One possibility is to create, based on the civil functions of the Corps, a semiautonomous national engineering agency analogous to, but different from, the National Institute of Standards and Technology. Such an agency could undertake public engineering projects, such as the wetlands restoration activities the Corps is now doing under its agreement with EPA, and programmatic activities as well. With its nationwide network of regional and division offices, the Corps is well suited to develop more effective applications and transfer programs for technologies initiated in the national laboratories and technical assistance programs targeted at public works engineers. The new civil Corps could be an independent agency or function under the auspices of either the Department of Commerce or DoD.

The engineering capabilities of the Bureau of Reclamation overlap to a certain extent with those of the Corps, occasionally creating competition over projects. As the roles of these agencies are reexamined, consideration could be given to merging the duplicative aspects of their respective missions and redefining the remaining activities to improve governmental efficiency.

Environmental Public Works

EPA's responsibilities are spelled out through the specific requirements of a number of laws, such as the Clean Air Act, the Clean Water Act, and the numerous laws affecting pesticides, fertilizers, and wastes. Standard setting and enforcement activities for drinking water, wastewater treatment, and solid waste disposal are each overseen in different offices, headed by associate administrators. Although its complex standards affect public services provided by every local government and many private entities and used by every citizen, the Agency has never been given a substantial budget for planning, technical assistance, or public information and education.

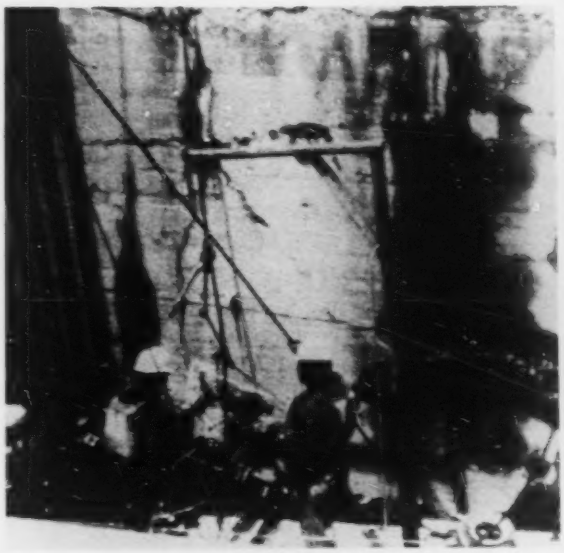


Photo credit: Army Corps of Engineers

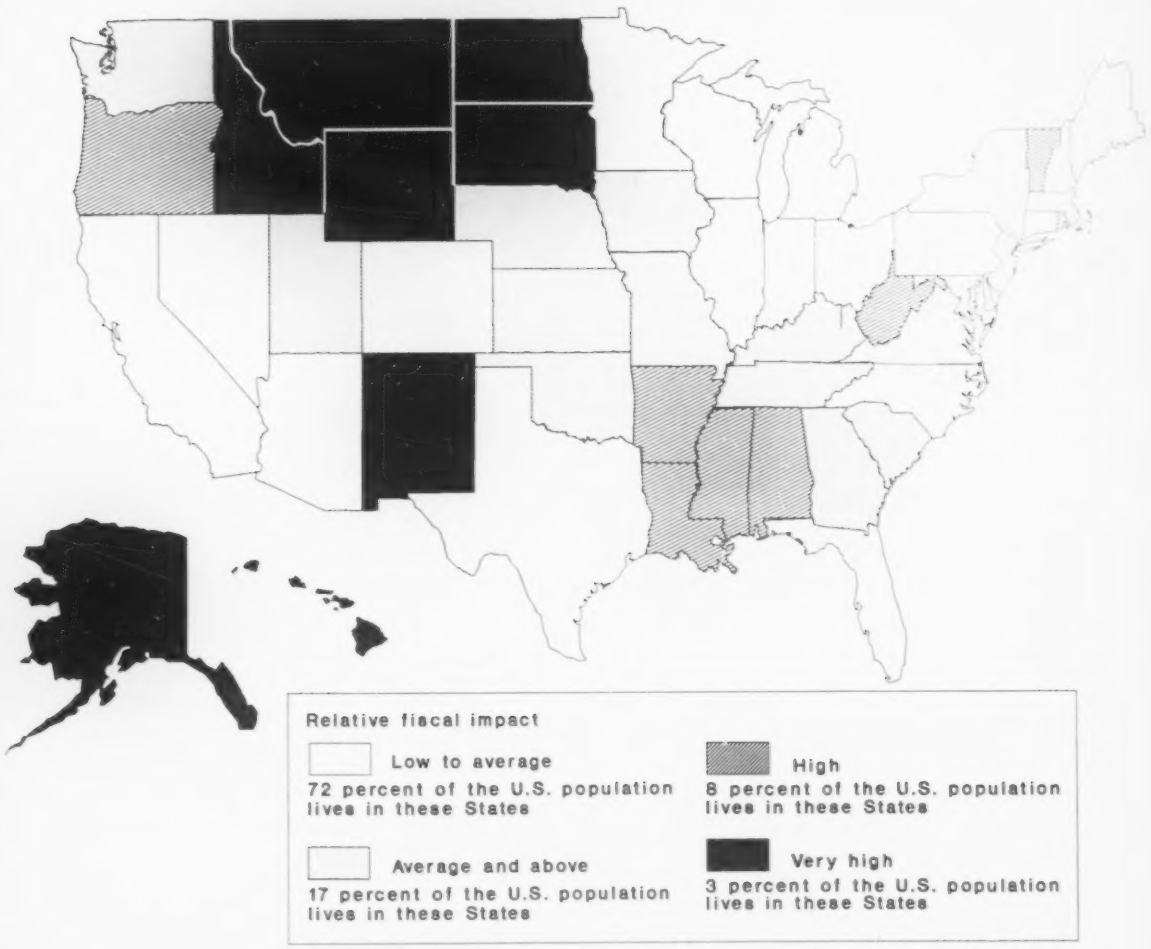
The Army Corps of Engineers has effective technology development programs for its engineers across the country.

The statutes determining EPA's activities have led to creation of an organizational structure under which each section of the agency pursues separate activities (see chapter 4 of the full report for further details). These programmatic divisions are reinforced by court decisions related to specific laws and by State laws or programs, making setting priorities for overall environmental protection a daunting challenge.

Standards and Enforcement

EPA has been required by legislation to set and implement standards for drinking water contaminants, wastewater treatment, municipal solid waste, and other environmental protection activities simultaneously with a reduction in Federal contributions for State and local construction grants. The Agency is thus in the position of having to enforce compliance with standards for public works, which may or may not provide a jurisdiction with additional health benefits commensurate with the costs of the facility and technology. The question must be raised of whether it is responsible government to take enforcement action for noncompliance with new standards that impose unreasonable costs relative to the

Figure 2—Projected Impact on States of Reduced Federal Aid for Public Works[a]


Relative fiscal impact
Low to average
72 percent of the U.S. population lives in these States
High
8 percent of the U.S. population lives in these States
Average and above
17 percent of the U.S. population lives in these States
Very high
3 percent of the U.S. population lives in these States

[a]OTA established an arbitrary 50-percent reduction in Federal aid to evaluate the impact on each State.
SOURCE: Office of Technology Assessment, 1991, based on information provided by Apogee Research.

health benefit, if no Federal assistance is available. **At a minimum, given the widespread gaps in financial abilities, technical information, and management know-how, Congress will want to address the issue of environmental enforcement policy for public systems facing severe fiscal stress imposed by Federal mandates.** As figure 2 indicates, over one-quarter of the States and 11 percent of the population potentially fit this category. One option is development and implementation of a formal strategy and program for staging compliance requirements. This could be coupled with stepped up Federal development and fielding of lower cost technologies for compliance. **Adequate funding for outreach and information programs, research, and evaluation of enforcement priorities is called for.**

Systems Management

The current EPA administrator is attempting to heighten the awareness of the interactions within the environment and to take steps to incorporate these into the Agency's programs, but it is far too early to tell whether the efforts will have any effect. Clarification of enforcement policy and the need for environmental systems management could be in-

cluded as part of legislation to make EPA a Cabinet department to bolster his efforts. However, whether or not the Agency becomes a department, legislative direction could help the EPA administrator (or secretary) to improve policy coordination and communications between the sections of the Agency and ensure that environmental public works requirements reflect the ways natural systems interact. **Congress could enact legislation requiring EPA to protect and manage the environment as a complex system and to clarify the role of the Agency in assisting public jurisdictions in complying with environmental standards.** Such a mandate would not guarantee improvement; as discussed elsewhere in this chapter, DOT has such a mandate for transportation, which it has not fulfilled. Nonetheless, such an action would provide additional leverage for broadening the present media-specific programs. Consideration could also be given to establishing formal mechanisms for regular review of cooperative programs for EPA, the Corps of Engineers, and the Bureau of Reclamation to avoid duplication and maximize resources.

OTA concludes that the fragmented congressional and executive branch responsibilities for public works impede setting policy goals that could lead to better investment decisions, more effective management, and better use of technologies. Research for this study showed that better data collection and program management changes are needed now, to address the needs of State and local governments and industry and ensure adequate investment and wise policy and technology decisions.

Difficult as management changes are, it would be unrealistic to assume that efforts made now to update Federal activities would continue to be appropriate for the indefinite future. Rather, the reverse is true; Federal public works programs and policies must be understood as dynamic and subject to rigorous periodic review and revision to keep them relevant and focused appropriately.

Congress

The current, atomized congressional oversight structure for public works is both inefficient and counterproductive. To cite a recent example, during the course of research for this study, OTA searched in vain for staff members on the committees with authority for financing or tax matters who had consulted with staff on public works committees about the impacts on States and municipalities of changes to the tax requirements for municipal bonds. The response from every committee staffer contacted was the same, "No, we didn't look at that." It took more than 2 years of sustained effort on the part of local officials to reverse sections of 1986 tax legislation that severely hampered their revenue raising ability.[10] **Financing, budget, and appropriations committees need to take into account the broad impacts of Federal tax and fiscal policies on the other governmental levels responsible for public works operations, areas in which authorizing committees have expertise.**

More thoughtful consideration of the complexities of public works issues and better policymaking might occur if Congress chose to review and consolidate widely dispersed committee responsibilities and develop better communications between committees of jurisdiction. If a complete overhaul of committee responsibilities is too daunting a task, special or ad hoc committees could be established to develop legislation on system problems—for example, to clarify EPA's mandate and identify important future directions for the agency.

Congressional oversight and responsibility for transportation needs reevaluating, with the goal of diminishing modal rivalries and developing legislation that leads to integrating the modes into an effective, national transportation system. At a minimum, mass transit responsibility could be consolidated with that for highways in the Senate, and the committees responsible for railroads could develop close working relationships with those with jurisdictions over highways and ports. Annual joint authorizing committee meetings and more frequent joint staff meetings to hammer out legislation that reflects the actual intermodal connections of the transportation system are other options.

Investment and Financing: Who Pays and How

> [the State's duty includes] . . . erecting and maintaining certain public works and certain public institutions . . . because the profit could never repay the expense to any individual . . . though it may

[10] A detailed discussion may be found in Office of Technology Assessment, op. cit., footnote 6, p. 49.

Table 4—Federal Outlays, 1960-90 (In percent)

	1960	1970	1975	1980	1985	1990[d]	1995[d] (projected)
National defense	52	42	26	23	27	25	22
Human resources[a]	28	39	52	53	50	51	56
Physical resources[b]	9	8	11	11	6	7	4
Net interest	8	7	7	9	14	15	9
Other[c]	3	4	4	4	3	2	9
Total Federal outlays (in billions of current dollars)	$92	$196	$332	$591	$946	$1,197	$1,477

[a]Includes Medicare, income security, and social security.
[b]Includes transportation, natural resources, and environmental and community development.
[c]Includes general government and undistributed offsetting receipts.
[d]Estimated.

SOURCE: Office of Technology Assessment, 1991, based on Office of Management and Budget data.

frequently do much more than repay it to a great society.[11]

Federal infrastructure programs have developed over many years to meet the concerns of the period, usually for purposes of national defense and economic development. As industrial and societal patterns have changed, the Federal Government has, with a few exceptions, found it far easier to add programs and requirements than to refocus or eliminate the existing ones. (Presidents Carter and Reagan were among the exceptions; each was quite successful in reducing the number of Federal support programs.) Although the importance of modern, well-maintained public works systems to National, State, and local economies should be a powerful impetus for changing outdated Federal policies, tremendous unmet needs accumulate well before Federal programs can be restructured to take account of them.

While several national studies over the past decade have recommended substantially greater investment in public infrastructure,[12] no sense of emergency has developed to spark the kinds of changes in social and fiscal policies and political attitudes that could make this happen. Over the last 30 years, Federal budget priorities have emphasized payments to individuals for social and health programs (see table 4) over investment in infrastructure. To ensure that some support for public works continues, dedicated trust funds fed by Federal user fees have been developed for transportation projects. Despite these funds, however, the overall trend in Federal policy and budget decisions has been to turn, slowly but steadily, to greater cost sharing by States and local governments.

Investment Issues

Federal programs have long supported economic development by providing capital support for construction of new facilities and heavily subsidizing some types of infrastructure while leaving States and local governments responsible for others. Never robust, Federal support for environmental public works, has dropped steadily, while at the same time, numerous strict environmental requirements affecting suppliers of municipal service providers have been enacted. **Laws mandating Federal standards for environmental public works that dramatically raise local government costs while simultaneously phasing out most remaining Federal aid seem perverse. Moreover, the emphasis on capital construction and the prohibition of assistance for improving operations in most Federal transportation programs is outdated.** Lack of space, high costs, and environmental considerations sharply limit the opportunities to build new highways or airports in urban areas where more capacity is most needed. Other solutions are called for. As Congress considers refocusing Federal investment policies for public works, the following issues are important to keep in mind.

[11]Adam Smith, *The Wealth of Nations* (Bungay, Suffolk, England: The Chaucer Press, 1979), p. 379.

[12]National Council on Public Works Improvement, *Fragile Foundations: A Report on America's Public Works* (Washington, DC: February 1988) is the most recent. The Council called for up to a doubling of public works expenditures, a general guideline which has since been supported by several studies of special segments of public works, particularly the U.S. Environmental Protection Agency, Office of Municipal Pollution Control, *1988 Needs Survey—Report to Congress* (Springfield, VA: National Technical Information Service, February 1989).

Photo credit: American Consulting Engineers Council

As communities in the South and West, such as Las Cruces, NM, grow at a rapid rate, expansion of environmental public works becomes necessary.

Fiscal Capabilities

State and local governments must balance their budgets annually, and right now, many face serious budget problems, exacerbated by the economic slowdown in late 1990 and early 1991.[13] Competition for revenue is keen among State agencies, with costs for Medicaid consuming a full 30 percent of some State budgets—in New York and Massachusetts, for example. Major population shifts and economic changes, such as the growth in the sunbelt States and the losses in some "rustbelt" cities and farm and prairie States, mean that some States will have much greater difficulty than others increasing their support for public works.

State fiscal problems can have a devastating effect on local governments, although some jurisdictions are in more vulnerable positions than others. Financing public works improvements is difficult for major urban areas, where public funds must meet other urgent demands, such as adequate housing, police protection, and schools. For some older cities where populations and tax bases are declining, maintenance has been deferred because of tight funding, causing serious decay in public works. As a consequence, public facilities provide inadequate service or function inefficiently, and are very costly to rehabilitate (see box B). These cities need help, but not every State is willing or able to provide it.

In other large urban areas, particularly in the South and West, rapid suburban growth and weak planning and land-use requirements have made developing an efficient transportation network seem impossible. In many such cities traffic congestion has slowed rush hour highway travel to 10 miles per hour averages. While their infrastructure needs are growth-related, they are likely to be as great as those of older cities. However, the economic base they can tap for funding is both broad and deep—and it includes private sector firms eager to participate in a growing market (see box C).

Another type of problem marks the poorest States and those with many small, rural systems. These barely have the resources to maintain existing systems and will find new construction to meet Federal environmental requirements prohibitively costly. (States in this category are indicated in figure 2 shown earlier.) Because Federal transportation grants have targeted capital construction and because of population and economic changes, some States have more of some types of public works than they can afford to maintain—such as the miles of Interstate highways in large Western States like Montana. Both small and large jurisdictions in rural States and large, older jurisdictions with huge public works backlogs and inadequate economic bases need more financial and technical aid.

As it reexamines public works investment policies, Congress could consider giving more Federal support to those States (and cities) where economic resources are limited and service needs are very high. How high a tax burden a State already places on its citizens (see table 5 for a summary) is another factor that could be considered. **OTA concludes that Federal investment in selected segments of public works must be increased to leverage State and local investment in growth areas and supplement resources in economically weak areas. Otherwise, the gap between local jurisdictions' ability to provide essential public services and the need for the services will continue to grow, with potentially serious consequences for the National, State, and local economies.** The most important targets for higher Federal spending for infrastructure

[13]Office of Technology Assessment, op. cit., footnote 6, pp. 57-61.

Box B—Predicaments of an Older City

The condition of public works in Philadelphia epitomizes the predicament of many large, older central cities. Capital outlays needed to replace and upgrade its public works contrast starkly to the city's fragile fiscal condition.

Water and Sewer Needs—Parts of the city's drinking water and wastewater treatment systems are over 100 years old and need extensive restoration and replacement. The City Water Department has proposed a $456-million capital improvement program for 1991-96.[1] Although drinking water currently satisfies U.S. Environmental Protection Agency regulations, officials are concerned about the feasibility and costs of meeting anticipated Federal standards for byproducts of corrosion (lead and copper) and disinfection. Under court order since 1979 to improve its wastewater treatment system, the city has rebuilt and upgraded treatment plants and eliminated ocean dumping of sludge, but the system, especially the supply piping, still needs major rehabilitation.

To finance the sewer and water improvement package, the Water Department must raise an additional $44 million annually beginning this year. The department initially proposed a 56-percent rate hike on top of a 20-percent raise in 1986, but recently adopted a plan to raise $27 million through increased rates and to cut expenditures by $16 million.[2] The department's high percentage of low-income customers makes covering all improvement costs through rate increases practically impossible. In fiscal year 1990, department collections fell $20 million below expenditures.

Transportation Needs—The capital cost to maintain and improve the regional highway and transit system and build some additional capacity is estimated at $14 billion spread over the next 20 years.[3] Projected operating costs, which include maintenance, are $4 billion for highways and $19 billion for transit. The city must bear most of the cost because many central city highways and subway facilities are in poor condition, exacerbated by years of inadequate maintenance. A 1985 study showed the city investing only 35 percent of the funds needed annually for street and highway maintenance and rehabilitation and 62 percent of those for mass transit's capital and maintenance needs. Comparing current outlays for regional transportation with recent needs estimates, the region will have a 40-percent investment shortfall.[4]

Fiscal Status—Philadelphia's fiscal problems are as serious as its infrastructure deficit. While employment in Center City Philadelphia continues to expand, the jobs are increasingly for high-level executives, managers, and technical support personnel, many of whom live and pay their taxes outside the city. The city's tax base is eroding, and fully 60 percent of all work trip travel is now intrasuburban.[5] In August 1990 the city's chief accounting officer warned that in 9 months the city might not have enough money to pay its bills, despite plans to borrow heavily.[6] The city's bond rating has been downgraded to junk-bond level, precluding new long-term borrowing and forcing officials to put together short-term credit packages to avoid insolvency.[7] To reduce expenditures, officials have cut operating programs; the police force is down 2,200 officers from its high in 1977,[8] for example. For help, local officials are looking for State and Federal aid and authority to raise local taxes and fees.

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[1]Standard & Poor, "Philadelphia Water and Sewer System," *Creditweek—Credit Analyses*, August 1990.

[2]Timothy Tettam, Standard & Poor, personal communication, Jan. 31, 1991.

[3]U.S. Department of Transportation, *National Transportation Strategic Planning Study* (Washington, DC: 1990), p. 17-2.

[4]Ibid., p. C-5.

[5]"Septa Studies Cross-County Commuting," *Railway Age*, vol. 191, No. 7, July 1990, p. 82.

[6]"Controller Warns on Philadelphia Funds," *New York Times*, Aug. 15, 1990, p. A-24.

[7]Frank Shafroth, National League of Cities, personal communication, Jan. 30, 1991.

[8]"Philadelphia's Jails and Courts Are Overwhelmed," *New York Times*, Aug. 15, 1990, p. A-24.

are indicated in table 6; those with stars need the largest relative increases.

Although budget negotiations are always arduous, a 20-percent increase in total national infrastructure investment seems both achievable and relatively modest. Congress increased Federal appropriations for transportation by about that amount in the 1990 budget, which should raise State expenditures, since most Federal appropriations require State matches. Moreover, State and local public works administrators should be able to spend 20 percent more without being overwhelmed, as they might be by a sudden, giant leap in funding.

Box C—Keeping Up With Growth

Population in the Houston metropolitan area more than doubled between 1960 and 1980 and now totals about 3.2 million, although the rate of growth has moderated. Houston has no zoning regulations, and unregulated development and unswerving devotion to private automobiles have created a low-density land-use pattern hard to serve efficiently with public transportation and sanitary facilities and have overloaded local streets and highways.

Highways and Public Transit—In 1980 voters approved a 1-percent sales tax to support the struggling Metro Transit Authority (METRO). Now 10 years later, METRO is spearheading a voter-approved metropolitan "mobility plan," that includes purchase of new buses to replace the existing, aging fleet, completion of a system of transitways to speed bus service, and a $600-million roadway improvement package to widen and resurface existing streets and build overpasses and underpasses at congested intersections. The roadway improvements were started first, and over 70 of 200 street projects are complete or under way, financed by the dedication of 25 percent of the sales tax revenues.[1]

Development of a rail transit system is the most controversial plan element. Critics complain that a rail system is not needed in Houston and that ridership can never justify the $1 billion investment, but METRO officials point to Los Angeles' freeway gridlock and air pollution problems as an example of what happens when a growing city relies exclusively on automobiles and highways for too long. The alignment for the rail line is still under discussion but a decision is expected in spring 1991; the financing package includes Federal funds ($115 million has already been committed), private sector contributions, and METRO funds.[2]

Drinking Water—During its years of rapid growth, Houston relied heavily on developer-built groundwater-based systems, but when subsidence (a sinking of the earth caused by groundwater loss) problems became acute, the State stepped in, setting up a regional authority to regulate water withdrawal from aquifers. Houston must switch to drawing its drinking water predominately from local lakes and rivers and is investing millions of dollars, in new facilities, including a new treatment plant and miles of additional pipelines to transport water to the city. Furthermore, costs for electrical power for treatment plants and chemicals used in treatment are expected to increase.[3] In addition, the city is replacing lead paint-lined storage tanks and 2,500 miles of small (less than 6-inch) pipe with larger more reliable lines.[4] To finance these improvements, Houston has increased user charges steadily:

[1]Anthony W. Hall, Jr., "We Don't Need Another Vote on Rail," *Houston Chronicle*, May 27, 1990, p. 1F.

[2]Gunter Koetter, "Rail Can Help Houston Avoid Los Angeles' Mistake," *Houston Chronicle*, June 24, 1990, p. 5F.

[3]City of Houston, Texas, "Preliminary Official Statement," regarding Water and Sewer System Revenue Bond Issue, Aug. 15, 1990.

[4]City of Houston Public Utilities Department, "Water Production," August 1990.

Regulations and Compliance

EPA estimates that total annual costs for the Nation's municipalities must rise from about $33 billion in 1987 to at least $54 billion (in 1988 dollars) by 2000 to meet some, but not all, of the new and proposed solid waste, water supply, and combined sewer overflow standards.[14] Small systems, serving fewer than 10,000 people, will be required to fund $6 billion in capital improvements to meet just one set of requirements, those of the 1986 amendments to the Safe Drinking Water Act. Many will need financial assistance to do so,[15] and meeting the standards or deadlines may be impossible.[16] However, the legislation gives little flexibility for responsible Federal, State, local, or private sector officials to develop innovative or cost-effective ways to comply. Policies that make local governments responsible for meeting Federal environmental mandates without commensurate Federal investment raise questions of fairness.

User Fees

Policymakers at all levels of governments must continually balance the objective of user pays with development goals and issues of ability to pay. To encourage development and because public works are regarded as a necessary service, user charges

[14]Apogee Research, Inc., *The Cost of Environmental Protection* (Washington, DC: U.S. Environmental Protection Agency, Office of the Comptroller, January 1990), p. 14.

[15]U.S. Environmental Protection Agency, Office of Drinking Water, unpublished summary data based on the Regulatory Impact Analyses prepared in accordance with Executive Order 12291, Nov. 27, 1989.

[16]Office of Technology Assessment, op. cit., footnote 6, p. 117.

21 percent in 1987, 9 percent in 1988, and 6 percent in both 1989 and 1990. The typical residential customer uses 7,000 gallons per month.[5]

While the scale of Houston's water system requires enormous capital investment, its size also supports the scientific and management capability to cope with Federal and State compliance requirements, which can overwhelm smaller systems. After finding that local laboratories could not provide the sophisticated water quality tests required by the U.S. Environmental Protection Agency (EPA) at a reasonable price, the city expanded its own laboratory, increased staff, and invested in automated equipment to do the testing. A special research and regulatory evaluation group evaluates the effects of proposed regulations on Houston's system, investigates technologies, and develops new treatment schemes. City officials maintain the staff work has paid off, because their unit costs are down,[6] but they remain concerned about complying with proposed standards for contaminants such as radionuclides and disinfection byproducts.

Wastewater Treatment—In 1987 the Texas Water Commission issued an administrative order fining the city $500,000 for permit violations and sewer overflows and establishing a compliance schedule for operational and capital improvements to meet Federal effluent discharge limits.[7] Since then, Houston has invested about $800 million in plant upgrading, consolidation, and new construction, and extensive sewer expansion and rehabilitation.[8] While the system now meets all EPA and State standards, the city plans to spend an additional $1.1 billion between 1991 and 1995 to replace narrow, worn-out lines and rebuild lift stations. These improvements are being financed by EPA grants, revenue bonds, developer impact fees, and user charges. As part of its financing package, the system will issue approximately $174 million in low-interest revenue bonds through the EPA-financed State Revolving Fund in 1990. User charges, which back the bonds, are set annually by the city council and currently average $19 a month.[9] Rates climbed 22 percent in 1985 and 1986 and more recently have risen about 8 percent a year—a trend that is expected to continue unless new Federal environmental regulations for cyanide, pesticides, and toxic metals require larger increases.

[5]City of Houston, op. cit., footnote 3.

[6]Ibid.

[7]Ibid.

[8]City of Houston Public Utilities Department, "Improvements in the City's Wastewater System 1982-1990," August 1990.

[9]Prior to 1974, Houston charged a flat household rate of 75 cents for wastewater treatment.

have traditionally been set below full capital, operating, maintenance, and replacement costs.[17] General revenue subsidies are usually necessary to cover capital costs, although in growth areas, beneficiaries may contribute land or cash to capital projects, reducing government costs. **While user fees can be increased by every level of government to correct existing underpricing, Federal and/or State financial assistance for local governments will be essential for most capital projects, especially for those jurisdictions with low per-capita incomes and large public works backlogs.**

Privatization and Private Sector Financing

Under circumstances where demand for certain services is likely to be high, private entities find investment in public works, particularly environmental services, attractive. Private water supply companies, for instance, have long flourished in many jurisdictions, as have private solid waste disposal companies. If private companies providing environmental public services can meet EPA and State standards, overcome public opposition on issues such as siting for waste disposal facilities, and make a reasonable return on investment, they can find multiple market opportunities.

However, private firms succeed in providing low-cost services primarily in situations where the market is large, and stable or growing. Many communities that must make major investments in public works are simply unable to generate adequate revenue from user fees to attract private capital. In other areas, private firms capture the lucrative segments of the market, leaving the less profitable ones for public agencies.

[17]U.S. Congress, Congressional Budget Office, *New Directions for the Nations's Public Works* (Washington, DC: U.S. Government Printing Office, September 1988).

Table 5—State Fiscal Summary

State	Per-capita income, 1989 (in dollars)	Fiscal[a] effort rank, 1988 (1 = highest effort)	Personal income tax revenue per capita, 1987	Sales tax rate, 1988	Gas tax rate,1990 (in cents)	Number of interstate miles rated deficient, 1988	Wastewater[c] needs, 1988
Alabama	$13,625	31	Average	Low	13¢	Low	Average
Alaska	21,656	3	No tax	No tax[b]	8	High	Low
Arizona	15,802	29	Average	Average[b]	17	High	Average
Arkansas	12,901	48	Average	Low[b]	14	Low	Low
California	19,929	27	High	Average[b]	14	High	High
Colorado	17,553	36	Average	Low[b]	20	Low	Low
Connecticut	24,683	49	Low	High	22	Low	High
Delaware	18,483	37	High	No tax	16	Low	Low
District of Columbia	23,491	2	High	High	18	Low	Low
Florida	17,647	46	No tax	High[b]	10	Average	High
Georgia	16,053	26	Average	Low[b]	8	High	Average
Hawaii	18,472	8	High	Low	11	Low	Low
Idaho	13,707	24	Average	Average[b]	18	Average	Low
Illinois	18,824	35	Average	Average[b]	19	Average	High
Indiana	15,779	30	Average	Average	15	Low	High
Iowa	15,487	4	Average	Low[b]	20	Average	Average
Kansas	16,498	15	Average	Low[b]	16	Average	Low
Kentucky	13,743	43	Average	Average[b]	15	Low	High
Louisiana	12,921	28	Low	Low[b]	20	Low	Average
Maine	16,248	22	Average	Average	17	Low	Low
Maryland	21,013	19	High	Average	19	Low	Average
Massachusetts	22,174	44	High	Average	17	Low	High
Michigan	17,444	7	Average	Low	15	High	High
Minnesota	17,657	5	High	High[b]	20	Low	Average
Mississippi	11,724	10	Low	High	18	High	Low
Missouri	16,292	47	Average	Average[b]	11	High	Average
Montana	14,078	18	Average	No tax	20	Average	Low

(continued on next page)

Table 5—State Fiscal Summary—Continued

State	Per-capita income, 1989 (in dollars)	Fiscal[a] effort rank, 1988 (1 = highest effort)	Personal income tax revenue per capita, 1987	Sales tax rate, 1988	Gas tax rate,1990 (in cents)	Number of interstate miles rated deficient, 1988	Wastewater[c] needs, 1988
Nebraska	$15,446	12	Average	Low[b]	22¢	Low	Low
Nevada	19,269	50	No tax	High[b]	18	High	High
New Hampshire	20,267	51	No tax	No tax	16	Low	Average
New Jersey	23,778	34	Average	High	11	Low	High
New Mexico	13,401	17	Low	Average[b]	16	Low	Low
New York	21,073	1	High	Low[b]	8	Average	High
North Carolina	15,198	39	Average	Low[b]	22	Low	High
North Dakota	13,563	11	Low	High[b]	17	High	Low
Ohio	16,373	25	Average	Average[b]	20	High	High
Oklahoma	14,154	33	Low	Low[b]	16	High	Low
Oregon	15,919	16	High	No tax	18	High	Average
Pennsylvania	17,269	38	Average	High	12	Average	High
Rhode Island	17,950	23	Average	High	20	Low	Low
South Carolina	13,654	20	Average	Average	16	Low	Low
South Dakota	13,685	32	No tax	Low[b]	18	Low	Low
Tennessee	14,694	42	No tax	High[b]	21	High	Average
Texas	15,702	45	No tax	High[b]	15	High	High
Utah	13,079	9	Average	Average[b]	19	Low	Low
Vermont	16,371	21	Average	Low	16	Low	Low
Virginia	18,927	40	Average	Low[b]	18	High	Low
Washington	17,649	13	No tax	High[b]	22	Low	High
West Virginia	12,345	41	Average	High[b]	20	Low	Average
Wisconsin	16,449	6	High	Average[b]	21	High	High
Wyoming	14,508	14	No tax	Low[b]	9	Low	Low

[a] Fiscal effort measures how much a State chooses to tax its revenue base compared with other States. (See app. A for a full explanation.)
[b] Local option sales tax permitted.
[c] Estimates of the relative State cost to build all needed publicly owned wastewater treatment facilities to meet the requirements of the Clean Water Act.

SOURCE: Office of Technology Assessment, 1991, based on variety of Federal and State data summaries.

Table 6—Priorities for Increased Annual Federal Infrastructure Spending

(★) Star indicates priorities for largest increases.

	1989 Federal spending[a] (in billions of dollars)	Priorities	20-percent increase in spending[b] (in billions of dollars)
Surface transportation total	**$17.9**		**$21.5**
Highways and bridges	13.8	★Maintain and improve condition of existing facilities. ★Expand system capacity through implementation of existing traffic management techniques, HOV and smaller lanes, signalization, and automated toll facilities. R&D on advanced technologies, e.g., intelligent vehicle/highway systems. Improve intermodal connections.	
Mass transit	3.5	Expand transportation system capacity and efficiency by adding transitways and improving intermodal connections, stations, terminals, and parking facilities. Modernize equipment and rehabilitate rails.	
Rail (passenger)	0.6	Modernize capital equipment. ★Implement high-speed rail in overcrowded corridors.	
Airports and airways total	6.6	Complete National Airspace System Plan. Expand system capacity through other advanced surveillance, guidance, and communications technologies. Expand system capacity with airport and runway construction. ★Improve intermodal connections.	7.9
Ports and waterways total	1.0	Continue to maintain and rehabilitate existing facilities. Expand capacity on a selective basis. Improve landside (intermodal) connections. Address environmental issues	1.2
Transportation total	25.5		30.6
Environmental public works, including wastewater and drinking water	2.8	★Construct, rehabilitate, and upgrade treatment facilities and collection and distribution systems, especially in large, older cities and small communities. ★R&D of low-cost technology and technical assistance for small communities and to overcome widespread resistance to innovation. Data collection and analysis of environmental system risk and assessment of regulatory consequences.	3.4[c]
Total Federal spending	28.3		34.0
Total all levels of government	140.0		168.0

[a] Federal spending totals include some noninfrastructure expenditures, such as for safety.
[b] A 20-percent increase is hypothetical. However, for surface transportation, it approximates the impact of spending the current Highway Trust Fund balance over a 5-year period.
[c] Because Federal budget projections forecast decreased funding for environmental public works, the $3.4 billion would be more than a 20-percent increase over current plans for Federal spending.

SOURCE: Office of Technology Assessment, 1991.

The "... potential advantages of privatization are probably slightly greater in solid waste disposal than toll roads, ..." [18] and transportation may or may not provide equally appealing private investment opportunities. The elapsed time between project conception, approval, and completion of construction is often a matter of years; work has just begun on publicly funded highway reconstruction projects that have been on the drawing boards for more than a decade, for example. This lengthy and uncertain timeframe poses difficulties for private investors. In addition to acquiring a site or right-of-way, the challenges facing private entrepreneurs wishing to participate in the large public works market include meeting Federal environmental requirements and obtaining approval of State supervisory bodies. Developers seeking to build a private toll road in Virginia, for instance, encountered numerous delays, first, in acquiring State permits, and subsequently in the Federal environmental impact assessment process. In addition, a real estate slowdown made some land owners, who had been eager to donate land for the highway hoping to reap returns on future development, much less interested in the deal, and some have held out for payment.[19]

Nonetheless, California plans four private transportation projects for construction on State-owned rights-of-way; arrangements permit return on investment from tolls and the value added by the privately developed transportation facilities.[20] Time will tell in both States whether the returns will be adequate to satisfy the private investors and also acceptable to State administrators charged with protecting the public interest.

Financing Transportation

The Federal trust funds for highways, mass transit, aviation, and waterways provide States and localities with more substantial Federal support for transportation projects than environmental public works enjoy. However, the variety of ways that Federal aid supports each transportation mode has led to different modal infrastructure problems (see table 7). When the Federal Government takes financial responsibility for maintenance and operations as well as assisting with capital costs for construction, transportation infrastructure has generally been kept in good condition. Infrastructure for harbors, inland waterways, and aviation falls into this category. While delays occur on the most heavily used portions of these (basically Federal) systems, more active demand or traffic management techniques can eliminate most of these capacity problems.

Surface Transportation

Surface transportation has drastically different characteristics, because Federal financing and investment have shaped actions taken by the State and local governments and some private entities (in the case of railroads and transit) that are responsible for infrastructure. State governments provide slightly more than 50 percent of highway funds, with about 22 percent coming from the Federal side, and the remainder from local governments. The emphasis in Federal programs on capital construction has made the State and local governments the owners of a far flung road system and a number of bridges, all of which need regular maintenance if they are to provide acceptable service. However, operations and maintenance are left almost entirely to the State or local owner (for further details, see chapter 3 of the full report), and fiscal constraints have caused almost universal cutbacks and deferrals for maintenance and rehabilitation programs.

Because their revenue raising options are limited by State laws, many local governments have not been able to fund road and bridge maintenance programs adequately. Many systems need operating improvements, too, to relieve delays caused by increases in traffic. But most large cities simply have not invested adequately in basic operational improvements, such as advanced traffic signal systems, largely because Federal grants are not available for the purpose.

Intercity passenger rail (Amtrak) receives Federal support for capital expenditures and about 30 percent of its operating costs. Intercity freight rail receives virtually no Federal support, except for

[18]Jose A. Gomez-Ibanez and John R. Meyer, "The Prospects for Privatizing Infrastructure: Lessons From U.S. Roads and Solid Waste," paper presented at the Conference on The Third Deficit: The Shortfall in Public Investment, sponsored by the Federal Reserve Bank of Boston, Harwich Port, MA, June 27-29, 1990.

[19]William H. Allen, vice president, Parsons Brinckerhoff Quade & Douglas, Inc., unpublished remarks at the OTA Workshop on Transportation Infrastructure Technologies. July 25, 1989.

[20]California Department of Transportation, Office of Privatization, "Privatization," unpublished document, October 1989, p. 1.

Table 7—Major Issues and Problems in Transportation Public Works

Transport mode	Condition	Capacity	Environment	Management and investment
Highways and bridges ..	10 percent of roads and 42 percent of bridges rated deficient.	Congestion and delays increasing in many urban and suburban areas; excess capacity in rural areas.	Air quality; land use; noise	Life-cycle management needed; large capital investment would be required to expand urban roadways to meet demand—a temporary solution, at best.
Mass transit	Structural deterioration of rail systems in older, urban areas.	Excess capacity available in most rail and bus systems.	Bus emissions	Roadway management enhancement needed to improve bus transit; life-cycle management and financing for rail transit; little recent R&D investment.
Rail	Generally good for large railroads; problems due to deferred maintenance on some regional and shortline railroads.	Excess capacity on most lines.	Waste disposal on Amtrak trains; for high-speed trains: noise, land use	Federal operating subsidies are needed for Amtrak to ensure reliable commuter rail services. Adequate, stable capital equipment funding could be established to help modernize the fleet and to expand capacity.
Ports and waterways ...	With a few exceptions, locks, dams, protective works, and channels are generally in good condition.	Locks are the bottlenecks on the inland waterways; delays can exceed 2 days at a few locks.	Dredging and dredged material disposal; noise, land use, and surface traffic problems at ports	Transportation users, especially on the inland waterways, require much greater General Fund subsidy than other transport modes; no cost sharing by nontransportation beneficiaries of navigation projects.
Airports and airways	The condition of airport and airway facilities rarely impedes traffic.	The number of available runways at the busiest airports is the greatest capacity constraint. The staffing levels and technological capabilites of certain airway sectors can be sources of delay.	Aircraft noise in communities surrounding airports; surface traffic congestion due to airports	Constructing new airports or physically expanding existing airports will be difficult for most communities. Technology advances could effectively expand existing capacity by up to 20 percent.

SOURCE: Office of Technology Assessment, 1991.

small amounts to construct safety improvements at grade crossings and intermodal transfer facilities, where highway monies have been used for some construction. Services provided by both Amtrak and freight railroads help relieve road congestion in major metropolitan areas.

Federal Grant Programs—Existing categorical grant programs for highways, which require only a 10 percent match for Interstate highway construction and up to a 25 percent match for other types of projects, have made States target capital construction and Interstate projects in particular, even when these may not be their most pressing requirements. To ensure that States also increase their own funding and that Federal funds are used for projects that are local priorities, **Congress could establish larger and more uniform match requirements for grants. For example, if the State and local match were set at 70 percent for all projects, from Interstate highways and railroad improvements to mass transit and airports, local priorities would not be skewed by the availability of Federal money for capital construction or for one mode over another. A slightly higher Federal match could be made available for States with the fewest resources.** Still a further possibility is to recognize the level of effort expended by each State to fund public works programs. For a profile of State resources and expenditure levels, see table 5 again. Some economists suggest that significantly higher State match requirements should be accompanied by open-ended Federal grants to provide maximum leverage for State spending; however, such a program would be politically very difficult to shape.[21]

User Pays v. General Fund Subsidies

Many major capital projects could never be built without Federal support, but the wide variation in Federal support for transportation modes has meant that some projects have been constructed that will never bring adequate financial return on investment measured in strict economic terms. Some of these projects, especially mass transit, commuter rail, and intercity passenger rail, bring transportation system and other societal benefits that justify even greater public subsidies. However, users of heavily subsidized systems that have excess capacity, such as many ports and waterways, and those that provide premium service, such as peak-hour aviation and commuter expressways, could pay more of their own way.

A comparison of the transportation problems summarized in table 7 with the funding patterns in table 8 highlights the need for revising Federal transportation investment and program policies. One option is to raise waterway user fees, particularly for recreational boaters, who are not now subject to the Federal marine fuel tax. Imposing a Federal axle-weight tax on heavy trucks is an equitable way to recoup the costs these vehicles impose for highway maintenance and rehabilitation above the amount they pay in fuel taxes.[22] Other options include eliminating restrictions on highway tolls and other forms of user funding for public works constructed with Federal funds. Tax treatment of parking and mass transit subsidies for employees could be equalized.

A Federal transportation pricing policy reflecting the full spectrum of system costs would incorporate operating and maintenance costs, as well as calculation of pollution and other indirect costs. It would encourage higher capacity passenger transport operations, such as car pooling, mass transit, and commuter rail, and mechanisms to reduce total energy use and environmental damage.

Fuel Taxes—are the major source of Federal revenues for transportation. Ideally, raising the Federal gasoline tax would encourage higher vehicle occupancy and more efficient use of the highway system, help address traffic congestion and air pollution problems, and reduce the need to build new highways. However, politically the Nation does not seem ready to accept fuel tax hikes of the magnitude necessary to make these sorts of impacts. Slow, steady, annual increases are more acceptable politically than large, sporadic escalations, especially when coupled with plans to raise appropriations yearly. Furthermore, annual Federal fuel tax increases could assure States of a more reliable funding stream and enable them to do better long-range transportation planning. For example, a 4-cents per gallon increase in Federal motor fuels taxes could be followed by increases of 2 cents per

[21]Edward M.Gramlich, "Financing Infrastructure Investment: Should Money Be Thrown at the Third Deficit?" paper presented at the Conference on The Third Deficit: The Shortfall in Public Investment, sponsored by the Federal Reserve Bank of Boston, Harwich Port, MA, June 27-29, 1990, p. 5.

[22]Kenneth A. Small et al., *Road Work* (Washington, DC: The Brookings Institution, 1989), p. 21.

Table 8—Federal Expenditures and User-Fee Revenue for Transportation, 1988 and 1989

	Federal expenditures		User-fee revenues[a]		Revenues as percent of expenditures	
	(in millions of dollars)					
	1988	1989	1988	1989	1988	1989
Highway	$14,424[b]	$13,898[b]	$14,288	$15,856	99%	114%
Transit	3,316[c]	3,595[c]	1,019[d]	1,017[d]	31	28
Rail	570[e]	594[e]	NA	NA	NA	NA
Aviation	5,192[f]	5,748[f]	3,189	3,664	61	64
Ports and waterways	1,383[g]	1,436[g]	203[h]	223[h]	15	16

[a] Does not include interest received on trust fund balances.
[b] Includes funds outlayed for Federal Highway Administration, National Highway Traffic Safety Administration, Forest Service for forest roads and trails, and Bureau of Indian Affairs for road construction.
[c] Includes capital and operating grants and limited research and development (R&D) spending.
[d] Revenue source is 1-cent per gallon from motor fuel tax.
[e] Amtrak funding and limited Federal R&D spending.
[f] Does not include expenditures for National Aeronautics and Space Administration, National Transportation Safety Board, or Department of Transportation Office of the Secretary.
[g] Corps of Engineers outlays for harbors waterways. Does not include Maritime Administration, Federal Maritime Commission, Coast Guard, or Panama Canal Company outlays.
[h] Includes Inland Waterway Trust Fund, Harbor Maintenance Trust Fund, and St. Lawrence Seaway Tolls.

SOURCE: Office of Technology Assessment, 1991, based on U.S. Department of Transportation, Office of Economics, *Federal Transportation Financial Statistics, Fiscal Years 1979-1989* (Washington, DC: May 1990).

year until the amount dedicated to transportation doubles the current 14 cents.

Because user-pays policies can adversely affect some classes of users, Federal decisions about raising user fees may require complementary actions to ensure that transportation is available to all. For instance, if an axle weight or other special tax were enacted for heavy trucks, this should be considered when other surcharges affecting trucks are evaluated.

Trust Fund Balances

Regardless of other steps taken to equalize national transportation support, Congress will need to find a way to address the issue of the transportation trust fund balances. Set up to be reliable mechanisms for financing highways, mass transit, aviation, and ports and waterways, transportation trust funds currently have large balances that are constant irritants to State and local officials facing massive project backlogs. Simply stated, Federal budget problems have so restricted expenditures that trust fund revenues (user fees paid for transportation services) have substantially outpaced allocations for transportation programs. Congress took a step toward addressing this issue when it raised 1991 spending ceilings for transportation programs; highway appropriations for 1991, for example, are close to 20 percent higher than those for 1990. By sustaining Federal spending for transportation at a level above trust fund revenues, fund balances can be effectively eliminated over 4 or 5 years. However, the overall domestic spending limits set in the 1990 Omnibus Budget Reconciliation Act require transportation to compete with other domestic programs for increased dollars. Thus, continued controversy seems inevitable unless a new budget agreement is forged.

Spending Priorities

The biggest problems for transportation infrastructure are inadequate capacity in major metropolitan regions and substandard conditions in many facilities across the country. For the short term, the top priorities are to redirect Federal investment toward programs for maintaining, upgrading, and extending the lives of existing systems and for increasing system capacity through technologies and management techniques. Under some circumstances, capital construction may be the best option. **Broadening categorical grant programs to permit greater flexibility for State and local governments in using trust fund monies, especially for maintenance programs, is probably the best way to ensure that short-term capacity and condition needs are met.**

Next in importance are reshaping Federal policies so that they encourage fair pricing and efficient infrastructure use and increase State and local spending, thus raising the total national investment. Making more Federal monies available for passenger and commuter rail and mass transit are options for improving the efficiency of transportation system use. Although commuter rail and transit have long been considered primarily regional or local services, a compelling case can be made for their

importance to interstate commerce, since each represents an alternative way to increase highway capacity in urban areas. Congress could also permit States and jurisdictions to use surface transportation grant funds for mass transit and passenger and freight rail improvements, if doing so is a priority to their regional or State transportation system plans. **Because Amtrak provides an invaluable alternative in heavily urbanized regions that have crowded highways and airports, a portion of an increase in Federal surface trust fund monies could be allocated to Amtrak for capital expenditures to enhance rail service. Surface access improvements that smooth connections to ports and airports and intermodal connections and transfers are other potential projects. Traffic signal improvements using some of the advanced vehicle and highway technologies reviewed in chapter 3 of the full report could reduce surface traffic congestion somewhat in urban areas. For rural areas, special attention could be paid to the mobility and freight transport needs of small communities, where no alternatives exist to private vehicles.** Table 9 shows the trade-offs associated with the choices.

For the longer term, an intensive Federal effort should be started now aimed at developing and implementing a strategic policy and applied research agenda for transportation to evaluate the trade-offs of alternative ways of addressing overcrowded intercity corridors and urban traffic congestion. This program must have funding support and participation from all the transportation modal administrations and from the industries that will benefit.

Financing Environmental Public Works

As Federal support for environmental public works has declined and new environmental requirements have become effective, many local governments will be hard pressed to meet the costs of upgrading their systems (see box D). Costs will more than double for about 20 percent of small, rural systems and some older, urban areas, the very jurisdictions that are least attractive to private investment and are hardest hit by declining Federal funding.[23] Under these circumstances, such cities are likely to find the aggregate fiscal impacts of combined sewer overflow control, solid waste disposal, and hazardous waste requirements more than they can handle in the immediate future. Funding for programs to comply with the new standards will compete with higher costs for schools and mandated social programs.[24] Moreover, real interest costs for public infrastructure have more than tripled over the last two decades, creating a bias toward short-lived, lower cost alternatives, which may cost more over the long term.[25]

OTA concludes that EPA has not come to grips with the compliance issues likely to occur because of the fiscal impacts of multiple new requirements on public works providers. Furthermore, widespread noncompliance with the new regulations is likely, especially among small systems and the Nation's oldest and largest cities, unless State and Federal financial and technical assistance is increased.[26] Options for technical assistance include development and field demonstrations of new, durable, and cost-effective technology options for both small and large systems and development by EPA of guidelines, based on addressing the most serious health and safety problems first and staging those projects where no unreasonable health risk exists (see chapter 4 of the full report for further details). Such guidelines could be useful for EPA, States, and local jurisdictions alike for setting priorities to schedule compliance and avoid enforcement actions.

Dedicated Revenue

Federal budget constraints notwithstanding, OTA concludes that the costs of compliance will be so burdensome that a congressional effort to address the issue is warranted. **Congress could consider establishing a dedicated source of Federal revenue to support State programs that assist localities in complying with EPA standards.** The source could be a broad-based tax, such as a dedicated

[23]Policy Planning and Evaluation, Inc., "Municipal Sector Study: Impacts of Environmental Regulations on Municipalities," unpublished report prepared for the U.S. Environmental Protection Agency, September 1988, p. ii.

[24]Office of Technology Assessment, op. cit., footnote 6.

[25]According to estimates by the U.S. Army Corps of Engineers. L. George Antle, chief, Navigation Division, Institute for Water Resources, U.S. Army Corps of Engineers, personal communication, July 20, 1990.

[26]Environmental Protection Agency officials consulted by OTA are concerned about potential noncompliance, but warn of the difficulty of making accurate predictions. One agency expert estimated that the number of jurisdictions in noncompliance might quadruple.

Table 9—Policy Choices for Transportation

Goal	Action	Trade-offs
Coordinate national transportation policies and treat transportation as a system.	Institutionalize a multimodal system by restructuring the Department of Transportation (DOT). Consolidate policymaking along broad modal lines (aviation, surface, and water) or functional categories (metropolitan passenger and intercity freight). Make commensurate changes to congressional committees.	Could reduce the number and extent of conflicting Federal policies and encourage decisions that address both competing and complementary aspects of transportation systems. *But*: Structural change is difficult and can be disruptive in the short term. No guarantee of effectiveness.
	Transfer fiscal and management authority for water transportation from the Army Corps of Engineers to DOT.	Would consolidate all civilian transportation authority within DOT. Problems in integrating Corps functions should disappear over time. *But*: Water resources aspects must be considered.
Encourage proper maintenance and management of existing and future public infrastructure. Improve condition and ensure longevity of systems.	Modify spending restrictions on Federal funds to favor maintenance over new construction, where appropriate; establish incentives for implementation of systematic maintenance programs.	Would encourage local authorities to give priority to maintenance. Using Federal funds for operations and maintenance, training, and supporting technologies could reduce total infrastructure costs over the long term. *But*: Does not address capacity issues.
	Give State and local authorities flexible options for generating revenues for transportation.	Could elicit substantial funds from tolls on federally funded highways, passenger facility charges at airports, congestion pricing, direct charges for infrastructure wear. *But*: Programs would require close oversight to ensure that new charges are equitable and that the monies are invested in transportation.
Ensure that future transportation investments reflect economic and social needs but are cost-effective.	Link Federal General Fund payments for transportation more closely to national transportation benefits and needs.	Would provide Federal incentives for more efficient system use. *But*: Would require new revenue sources to keep aviation and water systems operating. Service for hardship communities depends on continued general subsidies.
	Tie Federal capital investment to long-term planning and financial support of system.	Should encourage transportation system construction appropriate to the financial resources of users and other non-Federal interests. *But*: Requires State and regional planning and funding.
Reduce congestion and delay, and increase capacity.	Encourage physical expansion of infrastructure.	Could be a cost-effective option for increasing capacity. *But*: Environmental concerns, land-use restrictions, and high capital costs limit this option. In congested areas, delay reductions may be temporary as latent demand fills the new capacity.
	Support technology development and implementation to increase capacity of existing systems with technologies.	Can provide marginal (generally less than 20 percent total) gains in infrastructure capacity. *But*: In most cases, users would need to invest in new equipment.
	Implement market policies that change transportation demand patterns, such as congestion pricing, access restrictions on low-occupancy vehicles, and eliminating tax bias in favor of parking lots and employee parking.	Could shift traffic to underused times and locations and carry the same passenger or cargo volume on fewer vehicles. *But*: Complementary actions and Federal oversight to ensure affordable transportation options to all users would be necessary.

SOURCE: Office of Technology Assessment, 1991.

income tax surcharge, or a special-purpose fee, such as a carbon product or waste generator surcharge. If financial assistance is not feasible, a search for other solutions should be undertaken.

State Revolving Funds

Short-term options include expanding funding and functions for EPA's State Revolving Fund (SRF) program. Rather than phasing out Federal contributions by 1994 as currently scheduled, Congress could double the remaining authorization to $7 billion and expand the programs eligible for funding from SRFs to include drinking water and solid waste management. Although both water supply and solid waste have traditionally been financed locally, the scale of investment needed to meet new standards is beyond the capacity of many communities and their State governments.

Planning and Training

OTA's research also indicates that environmental public works planning for facilities and resource management is inadequate in most localities, and that many States and localities have difficulty attracting adequately trained personnel. Without a firmer commitment by States to planning and to implementing a coordinated land-use planning and capital budgeting requirement, local environmental problems are likely to worsen. Ensuring adequate and safe water supplies and providing wastewater treatment capacity in fast growing regions are among the types of issues that must be addressed. A Federal requirement for State funding support for planning and training is one option. **If agreement is reached on a dedicated source of funds for environmental public works, a requirement for each State to use a certain percentage for these purposes could be included.** Table 10 summarizes a variety of legislative options and their trade-offs.

Technologies and R&D—Making Public Works Work Better

Countless new technologies, such as system condition assessment and maintenance tools, communications, navigation, and information systems, and field construction techniques and better materials, have been developed in national laboratories, universities, and industry research departments. Many of them, with some adaptation, could help public works officials address both condition and capacity problems, do their jobs more productively, and make their systems operate more efficiently (see table 11). However, the technologies are often expensive to acquire, require expertise and special programs to implement and educating and training personnel to use them, and inevitably will bring new and unforeseen difficulties with them.

Despite the costs of purchasing and implementing new technologies, over the long term, they can play a major role in extending the lives of public works structures and provide substantial cost savings. For example, electronic control and data acquisition systems installed in water and sewer facilities permit operators in a central location to monitor remote flows and distribution system conditions in real time. Operators can use the electronic systems to optimize pumping operations and bring additional facilities on line to avoid overloading the system and causing damage. (For further information, see box 4-D in chapter 4 of the full report.)

Maintaining a Healthy Infrastructure

Although technology needs vary dramatically by public works category, common factors ensure healthy infrastructure across environmental services and transportation modes. The essential elements are rigorous approval standards from the outset of planning to the beginning of operations, regular inspection, quality workmanship and materials, preventive maintenance, and timely repairs. Meeting these requirements, even using current technologies, can save substantial sums of money; indeed, constructing quality facilities and maintaining them may provide the highest return on infrastructure investment.[27] If construction quality is poor and repairs are needed constantly, or if repairs to well-constructed facilities are postponed until major reconstruction is needed, the costs of providing alternate service or of traffic diversion and delays can equal the capital costs, doubling the total expense of a given project.

Calculations by the Army Corps of Engineers on the cost-effectiveness of maintaining and rehabilitating locks and dams indicate that regular maintenance and structural repair have effectively doubled the lifetimes of these large structures. "Barring a catastrophic event, these structures could last forever with good maintenance."[28]

Management Information and Communications Systems

Cost-effective public works management is based on accurate, current information about the location and condition of the basic infrastructure. Environmental public works managers need to know where the leaks are and must understand the contaminants in local drinking water, the contents of landfills, and the chemical components of industrial wastewater. State transportation officials must have similar information about highway and road systems and bridges, so they can plan and budget properly. However, since many infrastructure systems are old

[27]U.S. Congress, Congressional Budget Office, op. cit., footnote 17, pp. 14-15.

[28]James E. McDonald, research civil engineer, Coastal Engineering Research Center, Waterways Experimental Station, U.S. Army Corps of Engineers, personal communication, Oct. 10, 1989.

Box D—Small Towns and Big Public Works Problems

Rocksprings, Texas, is a remote agricultural community (population 1,350) 80 miles north of the Mexican border.[1] The average per-capita income of residents is under $6,000, and the city's annual budget is $221,000. How to provide wastewater treatment and solid waste disposal facilities that meet new Federal standards are pressing dilemmas for Rocksprings.

Rocksprings has no community wastewater collection and treatment system, and residents are trying to finance a $3.5-million wastewater treatment plant to meet State and Federal requirements. The city applied for a $2-million wastewater treatment plant construction grant (representing 55 percent of the project's costs) from the U.S. Environmental Protection Agency (EPA). The rest of the $3.5 million would be financed with a Farmers Home Administration (FmHA) grant for 20 percent of the remaining costs, and an FmHA loan for the balance. However, FmHA will not announce grant and loan recipients until after the EPA decision is made. If Rocksprings does not receive the FmHA funds, it will not be able to proceed with the project and will have to return the EPA grant money. Worse, the city will have spent $43,000 on preliminary engineering work and will have no source of funds to pay the bill. The alternative to constructing a major wastewater treatment facility would be to continue to permit individual treatment systems, but require upgrading to meet State standards at a cost to each homeowner of $12,000 to $15,000—more than the value of the average Rocksprings house.

Since 1931, Rocksprings has maintained a landfill just inside the city limits where waste material is burned weekly and the remaining garbage covered with dirt whenever possible. These procedures became illegal in September 1989, when Texas terminated all burning permits. Because of its unusual geology—solid rock 1,500 to 2,500 above sea level—the city does not have enough dirt to cover the waste, and if it complies with the order not to burn, its landfill will be little more than an open dump—equally illegal. The town does not have enough garbage to incinerate efficiently or to recycle in saleable quantities, nor are private companies available to provide disposal service. The area's Council of Governments is trying to develop a regional plan, but the great distances between cities, and differing standards between communities make this solution unlikely.

[1]Material on Rocksprings from Mary Simone, mayor, Rocksprings, Texas, at OTA Workshop on State and Local Infrastructure Financing and Management, July 7, 1989.

and were constructed in sections over long periods of time, much of this data must be collected and stored now. Many factors complicate the collection of good data about infrastructure condition, including the sheer size of many large systems, the fragmentation of management responsibilities, and inadequate personnel and technical expertise in many jurisdictions.

Technologies to acquire, sort, file, store, and analyze condition assessment information include robotics and television for remote and long-distance scanning, photologging and computer imaging of the results, and management information and communications systems. A host of nondestructive evaluation technologies can provide information about system condition, and when tied to computerized management information systems, permit targeting repairs, maintenance, and reconstruction to areas of greatest need. (See chapter 5 of the full report for further details.) Managers find these management tools invaluable; indeed recent calculations indicate that 40 percent[29] of State capital budgets are spent on information and communications technologies.[30] Yet few Federal grant programs directed at public works permit monies to be used for purchase of hardware and technology equipment.

Field Construction

Field construction and rehabilitation techniques, such as casting large segments of a facility near the site, then placing them at night so as to minimize disruption of normal service, are usually developed on a project-specific basis, often by the contractor. Public sector research into this vital segment of public works is almost nonexistent, and industry expenditures, estimated at less than 0.3 percent of

[29]This does not include construction; the figure falls to 25 percent of capital equipment expenditures when construction costs are incorporated.

[30]Bradley S. Dugger, "Technology as a Management Tool," unpublished remarks, Governor's Infrastructure Conference: Managing for Environmental Quality, Nashville, Tennessee, Jan. 17, 1991.

Rocksprings could solve the problem by unincorporating. State law mandates that all counties with a population of 30,000 or more and all cities, no matter how small, must provide for the disposal of solid waste within their jurisdictions. Because Rocksprings' county has fewer than 30,000 people, the city could unincorporate, close its landfill, and be in compliance with State regulations. However, the cost of closing the landfill is $400,000, almost double the city's annual budget. Rocksprings is a stunning example of the dilemmas associated with establishing appropriate national environmental standards.

Ionia, Michigan, a rural community of 6,000 located midway between Grand Rapids and Lansing, was served by two rail lines until about 10 years ago. However in the early 1980s the Grand Trunk Western Line sold out to its competitor, Central Michigan Railway (CMR), and now local officials and businesses are fighting to retain the one remaining line and the two trains a day that connect Ionia to Owosso, a regional center 41 miles to the east. Last year CMR, a small class III railroad, petitioned the Interstate Commerce Commission (ICC) for permission to abandon the segment of track connecting Ionia to Owosso, including six stations along the way. The railroad claims the line's high operating costs and low projected revenues make service uneconomic and that local businesses can ship by truck; when the company offered to sell the line to the State on a leaseback basis, the State declined.

Ionia and its surrounding townships boast close to 1,000 industrial jobs. Local industries produce tires and automotive components on a contract basis for major automobile manufacturers, most of whom require their contract suppliers to have access to rail service as an option to truck transport—"no rail; no contracts." Owners of the lumber companies, the fertilizer plant, and grain elevator claim they cannot switch to truck transport because specialized trucks and equipment needed to handle their products are not available locally.[2] Many of the town's jobs could be lost and the prospects for modest growth in the region changed dramatically by the proposed abandonment;[3] towns east of Ionia fear the proposed abandonment would eventually cut off their rail service.

Local governments are already borrowing to finance a regional wastewater treatment plant, and while the area's business community has formed an alliance to fight abandonment, they cannot afford to buy the line. The region's economy is currently too good for it to qualify for hardship aid from Federal or State sources, because several State corrections facilities in Ionia provide stable service jobs. Civic leaders do not know where to turn for help.

[2]James Mooney, president of the Kent, Ionia & Clinton Rail Association, statement prepared for the Interstate Commerce Commission, June 11, 1990.

[3]Ruth Hewitt, executive director, Ionia Chamber of Commerce, personal communication, Aug. 14, 1990.

gross annual sales in 1987, have continued to drop.[31] Keeping any facility operating in as close to normal a manner as possible during repair is a top priority for public works officials. Consequently, more systematic attention to techniques for in situ work is warranted in public sector research programs.

Materials

Materials selection, both for new construction and for rehabilitation, can make a major difference in long-term facility condition and costs, if adequate corrosion protection is ensured. Corrosion problems affect both concrete and steel, the two most commonly used construction materials. Attention to corrosion in the design, materials selection, and construction phases of a project and investment in protection up front at small additional cost can save millions of dollars in repair and maintenance costs.[32] Using cathodic protection and protective coatings and controlling stray electrical currents help prevent corrosion and prolong lives of public works structures. (For further information, see chapter 5 of the full report.)

Preliminary results from the Strategic Highway Research Program (SHRP) indicate that paving materials perform differently in diverse parts of the country, and assumptions about the long-term performance of many concrete and asphalt pavement additives are premature (for further details, see chapter 5 of the full report). Research on the effect of tire wear on highway pavement life is ongoing, and before conclusions are reached about changing truck weight limits, the long-term effects of different tire configurations and truck weights on pavement

[31]U.S. Congress, Office of Technology Assessment, "Construction and Materials Research and Development for the Nation's Public Works," staff paper of the Science, Education and Transportation Program and the Energy and Materials Program, June 1987, p. 1-11.

[32]National Bureau of Standards, *Economic Effects of Metallic Corrosion in the United States: A Report to Congress by the National Bureau of Standards*, NBS Special Publication 511-1, SD Stock No. SN-003-003-01926-7 (Washington, DC: 1985).

Table 10—Options for Federal Environmental Public Works Policies

Goal	Action	Trade-offs
Increase national investment and assist communities in meeting costs of complying with Federal environmental public works standards.	Extend and fully fund SRF (State Revolving Loan Fund) authorization past 1994 (current expiration date).	Helps States meet local needs, provide expected funds, and ease planning. *But*: Requires additional Federal outlays. These could be raised by new broad-based or special-purpose taxes.
	Amend Clean Water Act or enact other legislation to expand SRF project eligibility to drinking water and solid and hazardous waste facilities; increase appropriations.	Increases local access to funds for facilities required by new Safe Drinking Water Act, wastewater treatment and solid waste regulations; could build on existing SRF program structure. *But*: Requires more outlays and intervention into area of traditional local government and private sector control.
	Increase State match to leverage more State investment.	Encourages larger State commitment; gives incentives for better State program management. *But*: Poor States may be unable to meet higher match; may discourage program participation.
	Develop and implement a risk management approach for environmental public works to guide enforcement, and permit local communities to address most serious risks first.	Makes local compliance more likely because communities can adapt solutions to local needs and conditions. *But*: Success depends on local risk assessment and planning, and availability of State supervision and technical assistance.
	Earmark a Federal revenue source for financing environmental public works—a share of an existing tax or a new tax (e.g., carbon or other product related to environmental pollution).	Ensures financing for resolving long-term environmental problems that are not suitable for annual budgeting. *But*: Reduces Federal flexibility by earmarking funds.
	Combine Federal community environmental loans and grants into a State block grant program administered by EPA.	Increases efficiency by combining administration of programs now scattered throughout agencies; reduces Federal administration of detailed project requirements and cuts local costs. *But*: Adds responsibility for EPA, which is already over burdened. Eliminates most Federal control over spending; agencies often resist losing programs.
	Establish Federal bond guarantee program for small communities for environmental facilities.	Provides many communities with access to private credit market; limits Federal role. *But*: Program costs due to defaults hard to estimate; requires new administrative entity.
Encourage greater use of technologies to bolster efficient operation of facilities.	Combine scattered Federal technical assistance efforts and form an Environmental Technical Assistance Program, administered by the States.	Fills a pressing need for engineering, planning, and financing expertise, especially among small communities; cost-effective.
	Provide financial incentives or regulatory requirements that communities initiate and adhere to facility maintenance programs and provide additional funds for facility planning in conjunction with regional planning organizations.	Increases efficiency and performance by encouraging maintenance and attention to life-cycle costs. Efficiency gains from planning environmental facilities on a regional basis.
Use market incentives in addition to regulations to address environmental problems.	Impose charges or taxes on pollutants to discourage use and to raise revenue (e.g., taxes on carbon products or waste generation).	Offers alternatives to achieve environmental goals more flexibly and at lower cost than traditional regulations; a logical extension of the polluter pays philosophy. *But*: Unpopular with the producers and users.
	Reward local effort to impose user fees that cover full cost of service as a means of financing facilities and limiting demand.	Addresses current undercharging for environmental services. (EPA requires full cost fees for wastewater facility loans program.) *But*: Provisions would need to be made for low-income users.
Encourage EPA to develop risk management guidelines for public works and systems approach to environmental and health issues.	Develop policy statement for inclusion in pending legislation to elevate EPA to Cabinet status.	Gives EPA a clear legislative directive to evaluate enforcement priorities for public entities and to pursue cross-media regulatory programs, research, and planning, with potential to break down program barriers and reduce conflicts. *But*: Media-segmented bias will be hard to change; no guarantee of success.

SOURCE: Office of Technology Assessment, 1991.

Table 11—Technology Priorities for R&D for Maintaining Infrastructure Condition

Technology	Uses	Status	Comments
Nondestructive evaluation equipment; sensing and measurement	Measure various physical properties for monitoring and control; examine physical or mechanical properties of equipment or structure without affecting it permanently.	Developed for industrial use; public works market is secondary for many suppliers, often tied to preventive maintenance programs and automated inspection systems.	Many private sector users; cost and expert interpretation of results limit local government use; harsh public works environment and cost of high-tech equipment are limiting factors. *Most useful for highways and bridges, ports and waterways, water, wastewater treatment, rail systems.*
Information and decision systems	Provides database organization and manipulation capabilities for the wide range of data and information needed for public works management.	Many database systems are readily available.	Cost and technical capabilities are limiting factors; value of good data is difficult to evaluate. *Useful for highways and bridges, transit, rail, water, wastewater treatment, solid waste.*
Communications and positioning systems	Traffic management and control and remote infrastructure monitoring.	Technology exists for nearly every need; private sector use is increas-ing. Well established in aviation; crucial to future air traffic enhancement.	Microprocessor improvements have increased reliability and performance and lowered costs. Great potential in all fields. *Most useful for ports, water, air, highways.*
Field construction technologies	Improve ease and speed of construction or minimize disruption in developed areas.	Numerous technical opportunities.	Industry is slow to adopt new methods; some methods require new technical skills. *Useful for highways, transit, rail, water, wastewater systems, solid waste disposal.*
Materials and corrosion prevention	Improve durability and resistance to operating stress and protect against premature deterioration and failure.	Many new materials and techniques have been tested and applied; their use and use of corrosion prevention is increasing but still is not widespread.	Industry is slow to adopt new materials and methods; designers are reluctant to consider approaches that are not well established. *Useful for highways and bridges, ports and waterways, water, wastewater treatment systems, solid waste.*

SOURCE: Office of Technology Assessment, 1991.

must be analyzed. Economists have begun to note the importance of materials and to calculate user charges that could offset the costs of thicker, more durable pavements, for example.[33]

The key for policymakers in making technology-based decisions is to remember that any technology change must be accompanied by the appropriate policy change, or the benefits may not be realized. Furthermore, changes in operations by any industry segment, such as airlines or the trucking industry, to optimize its operations within a new policy and technology framework may alter the long-term impacts of any new technology-based standards and policies. Federal and State decisionmakers would do well to keep in mind the need to revisit policies on a regular basis because of the dynamic nature of the way public works services are used.

Technologies To Increase Capacity

While the poor condition of the physical system is the dominant problem for public works in many urban and most rural areas, highways, airports, and wastewater treatment systems in large, urban jurisdictions also have capacity problems. These manifest themselves in restrictions on development and in traffic congestion and delay. Perhaps the most difficult aspect of capacity problems is that technology can make relatively little long-term impact, increasing capacity by between 10 and 20 percent at most. In many cases, any capacity created by new technology is likely to be consumed immediately by users who had been finding other means of meeting their needs. The policy and political decisions to manage or shift demand, which must accompany technologies to ensure adequate capacity, are far more problematic.

[33]Clifford Winston, The Brookings Institution, "The Case for Efficient Infrastructure Policy," paper presented at the Conference on The Third Deficit: The Shortfall in Public Investment, sponsored by the Federal Reserve Bank of Boston, Harwich Port, MA, June 27-29, 1990.

Photo credit: American Society of Civil Engineers

Attention to corrosion protection in the design, materials selection, and construction phases of a project can save millions of dollars in maintenance and repair costs—and help ensure safer infrastructure.

Environmental Public Works Capacity

For environmental public works, the most promising technologies to address capacity issues are those that detect leaks and permit repair without disrupting service, those that can prevent water loss to evaporation, and those that reduce demand. Among technologies applicable to these needs are a variety of trenchless technologies (see chapter 5 of the full report); low flush toilets; dual water supplies that provide separate household and outside water; and recycling, reuse, and source reduction for municipal solid waste.

Although available now, most of these technologies are not in widespread use, because Federal and State public policy decisions that would make them cost-effective options have not yet been taken. Policy tools include full cost of service pricing, with appropriate consideration of ability to pay, and a larger commitment to resource conservation in all user segments. If water shortages of the magnitude now felt in southern California become more widespread and the cost of new technology-based facilities increases (desalinization is again under discussion in California), conservation is likely to become a more attractive choice, and the technologies will be understood as being cost-effective.

Photo credit: American Society of Civil Engineers

As water shortages of the magnitude now felt in southern California become more widespread, conservation is likely to become a more attractive choice.

Transportation System Capacity

Technologies that can increase transportation system capacity, such as radar, improved traffic flow procedures and signal equipment, computers, and electronic communications systems, are available for waterways, mass transit, and highways, but are not yet widely used, except in aviation. Moreover, the expansion possibilities they offer (20 percent at most) are not likely to be large enough to meet demand for long in fast growing regions. **Nonetheless, the short-term benefits in reducing congestion make improving traffic flow a top priority.**

Where construction of larger facilities is impossible, planning and land-use controls and pricing or other incentives to shift demand will also be required to cope with the expected growth in both highway and air travel. While substantial investment in system analysis, equipment, and personnel training will be necessary, these costs will be offset by reducing the need for acquisition of expensive, additional land and construction. Some intermodal technologies are under research in the private sector,

but the work does not address the broader needs of a national transportation system.

Technology Priorities

Safety and public health concerns and the impact of a major facility, such as a large, new harbor development project, on land transportation, on the environment, and on community life are major issues that affect public works. **The technologies offering the most potential for shedding light on these and other complex public works problems are management information and condition assessment tools, maintenance-related technologies, and techniques for increasing capacity where new construction is not feasible. OTA concludes that these are top priorities for immediate attention as Congress considers how to reshape infrastructure programs.** As a practical first step, Federal grant programs could be expanded to permit the purchase of management equipment, including hardware and software. **However, without investment in complementary programs (now missing in almost every public works program) to ensure a sufficiently prepared work force, no technology will fulfill its potential role.** Any changes to Federal programs must take these indispensable adjuncts into consideration.

Education and Training

Technologies are useless without an adequately educated and trained work force to manage, operate, and maintain them, and the scarcity of trained public works managers and technicians was a recurrent theme throughout the course of this study. Managers and officials hold that the public works sector is losing its best-trained people to the private sector, with its higher salaries, and to retirement much faster than they can be replaced. Moreover, new technologies often require skills that are not taught in vocational or high schools, and in some cases, not even in universities. In fact, most university civil engineering departments, the training grounds for many public works managers, do not teach courses in nondestructive evaluation or maintenance management, which will eventually be basic tools for public works departments. **Every level of government needs to give more attention to these problems.** The Federal Government could target funds to support university research for public works to attract students back to civil engineering. Federal programs that support university engineering programs (such as that of DOT's University Centers) could require courses in maintenance management and capacity enhancing technologies and management technique.

States, too, can play larger roles through their universities and public works agencies. To cite one model, Tennessee uses the University of Tennessee, a land-grant school, as an effective public works technology-sharing arm for its local governments.[34]

Technology Management in the Public Works Arena

Exciting as new technologies are, **OTA concludes that better system management and making good use of existing technologies can also help public works managers improve the efficiency and productivity of their operations.** For instance, the procurement processes used by public agencies at all levels of government are generally rigid and inflexible. Developed over time to ensure honesty and fairness, they have become very effective barriers to adoption of new products and procedures. The low-bid procurement process does not always ensure the most cost-effective or highest quality purchase, especially if prequalification requirements are lax. **Federal grant requirements need to be reexamined and reshaped to encourage public officials to make greater use of procurement approaches, such as competitive negotiations and concurrent design-build, which have proven successful for private projects.** States may need to revise their requirements as well. (For further details, see chapter 5 of the full report.)

Operational Testing and Demonstration

Public works services are expected to be reasonably priced and reliable; they do not lend themselves to trial-and-error methods of selection. Local officials use tried and true technologies, because they do not have the analytical resources to assure the performance of a new technology and cannot afford the political or operational risk of failure. Thus, liability concerns haunt suppliers, manufacturers, and public officials as well, and manifold difficulties confront the developer of a new technology for public works. Many a technology entrepreneur is frustrated by rejection of numerous attempts to have

[34]Thomas A. Ballard, assistant vice president, Institute for Public Service, University of Tennessee, personal communication, Jan. 17, 1991.

Table 12—Environmental Protection Agency Laboratories

Office	Number of laboratories	Number of staff	1989 budget (in millions of dollars)
Office of Modelling, Monitoring Systems, and Quality Assurance	3	441	$84.0
Office of Environmental Engineering and Technology Demonstration	2	282	78.5
Office of Environmental Processes and Effects Research	6	407	59.3
Office of Health Research	1	286	46.2
Total	12	1,416	$268.0

SOURCE: Office of Technology Assessment, 1991.

a development tested so a track record can be established.

Cooperative, joint efforts between private sector suppliers and government to demonstrate and evaluate new technologies for safety, durability, and long-term costs are excellent ways to spread the risk and overcome some of the difficulties of the procurement process for new technologies. **OTA concludes that supporting such development and evaluation programs is an essential Federal function that has been inadequately supported in every public works field except aviation and water transportation. Increasing DOT investment in such programs for highways, mass transit, and passenger rail by 50 percent and doubling or tripling EPA's spending would bring substantial returns in improved public works performance. SHRP's cooperative approach provides a model.**

Public Works R&D—Almost an Oxymoron

Although the total dollars spent by the Federal Government on research for public works are substantial, a closer look reveals that some areas have been grossly neglected. Federal R&D has always targeted specific problems identified by the funding agency; consequently, research in federally funded laboratories and institutions is oriented toward the concerns of the sponsor and usually involves numerous, disparate projects. For example, the Department of Defense has supported development of artificial intelligence systems for defense purposes, and the Corps of Engineers has done a great deal of work on maintenance for waterways. (See chapter 6 of the full report for further details.) EPA research laboratories each focus on providing technical support for a part of the regulatory process (see table 12); even the technology demonstration programs do not target the needs of public works providers. (See chapter 4 of the full report for further details.) Finally, each DOT agency funds studies to carry out its mission (as shown in table 13). No agency has focused on R&D programs to make public works services more cost-effective and productive.

Moreover, State and local public works officials, those who stand to benefit most from the results of Federal R&D, do not utilize research products until they have been through a long process of development, evaluation, and modification. This length of time and the lack of investment in technology development and evaluation have made public works an unattractive target market for both public and private research facilities, leaving large gaps.

The Federal Role

The Federal Government is the one entity with sufficient scope and resources to fund additional public works R&D, an especially important role for it to fill since State and local governments are the primary service providers. **However, Federal investment in R&D to address the condition and capacity problems faced by public works providers across the country is inadequate. Commitment of substantial additional Federal resources for R&D is called for, with the focus on both immediate problems and long-term alternatives.**

Some additional funding could be provided by private sector beneficiaries through assessment programs. Care is needed, however, when pursuing private funding for R&D, and private funds can never substitute completely for public support. The R&D agendas for private entities are different than those of public agencies, and finding the appropriate ways to capitalize on private sector interest and resources without skewing public goals presents a challenge.

Furthermore, to enable even small jurisdictions to benefit from R&D results, technology transfer and technical assistance efforts must be stepped up. **To increase financing for R&D, Congress could require that recipients set aside a percentage of Federal grant monies to be used for R&D into**

Table 13—Department of Transportation Public Works Research and Development

Agency	FY 1991 funding (millions of dollars)	Funding source	Comments
Federal Highway Administration			
Highway Planning and Research Program	$51[a]	A portion of 1.5 percent set-aside of Federal-aid construction funds from the Highway Trust Fund	Supports State and local planning, traffic measurement, and other research
National Cooperative Highway Research Program	8	5.5 percent set-aside of HP&R funds	Contract research managed by Transportation Research Board (National Research Council)
Staff research	18	Highway Trust Fund	30 percent in-house research; balance in contracts
Strategic Highway Research Program	30	0.25 percent set-aside from Highway Trust Fund	Contract R&D focused on highway construction; 5-year program
Federal Railroad Administration	15	From appropriated budget	In-house and contract R&D (does not include $6.15 million for magnetic levitation rail initiative)
Urban Mass Transportation Administration	2	From appropriated budget	Development projects
Research and Special Programs Administration			
Volpe National Transportation Systems Center	115[b]	Fee-for-service reimbursements	Two-thirds of research is for DOT, coming out of other administrations' budgets; one-third is for extramural clients
Federal Aviation Administration	205	From appropriated budget	63 percent of budget for in-house R&D
Total	***$444***[c]		

[a] Total funds for the Highway Planning and Research (HP&R) Program are about $153 million, most of which is used for planning. The portion used for research is $53 million.
[b] Estimate for Department of Transportation (DOT) research.
[c] Total does not include the one-third of Volpe National Transportation System Center's total budget that comes from other sources.

SOURCE: Office of Technology Assessment, 1991, based on information from the Federal Highway Administration, Volpe National Transportation Systems Center, and the U.S. Department of Transportation.

technologies, with an emphasis on those applicable to maintenance. Resources are also needed for long-term planning (with a stipulation that plans be based on a system needs analysis and tied to a capital budget), and for technical assistance, education, and training. The amount of Federal money currently available for environmental public works projects is too small to provide for any of these priorities. If a decision is made not to increase Federal environmental grants, special attention to these needs is warranted during the next legislative authorization cycle.

Large, Complex Systems Research

A closer look at the research programs of EPA and DOT highlights the woeful neglect of data collection and systems-level research for public works problems, especially on the impacts of transportation on the environment. These are important subjects for Federal attention, and Congress could consider requiring both DOT and EPA to develop and implement comprehensive system data collection and research programs. Because transportation and environmental problems are so tightly interconnected by government planning and land-use requirements, the two agencies could also be asked to develop and fund jointly an interagency research program through the Volpe National Transportation Systems Center and one of EPA's existing laboratories.

Some efforts to integrate research are currently under way in both agencies. Rigorous top-level review of long-range research plans developed by sections of each agency is called for to ensure that new goals encompass more than a reshuffling of existing research and address top-priority current problems. A broad-based outside advisory committee including State and local government and industry officials could be formed to review any interagency programs.

R&D for Environmental Public Works

Over the long term, EPA could develop and implement a comprehensive, strategic approach to setting standards and facilitating compliance, based

on addressing the most serious risks first. A vigorous research, development, and technology transfer program is needed into alternative technologies for meeting standards, particularly for small systems, where there is "no unreasonable risk to health."[35]

Transportation R&D

Transportation R&D has its own noteworthy shortcomings. First, with the exception of some D T programs under FAA and FHWA sponsorship, on. limited Federal investment has been made in research into alternatives to existing technologies. Field construction and maintenance techniques, high-speed trains of several types, and longer lasting surfaces for highways are among the many possible technology alternatives already available in other countries. However, evaluating the case for a major shift to a new technology, intelligent highways, tiltrotor aircraft, or magnetic levitation rail for example, requires strategic planning for technology development and careful thought as to the appropriate Federal role, if any. Such a change in a substantial part of an already large transportation system would require commitment of Federal funds and consideration of how to tie new infrastructure facilities in with existing system components. Such tasks cannot be undertaken quickly or lightly (or cheaply).

It is time for Federal officials to think seriously about the best ways to capitalize on technology options for addressing public works problems and develop research and action programs. When alternatives become essential in this country, the United States may find it cost-effective to purchase foreign technologies and adapt them to domestic needs. The long-term costs and trade implications of R&D policy decisions could be very large and seem to warrant a greater investment now in R&D.

Huge discrepancies characterize R&D funding among the DOT agencies; FAA and FHWA have the only research budgets worth mentioning. FAA's R&D appropriations have held steady because modernizing air traffic control equipment has been a top Federal priority, and most of the agency's expenditures have been for that purpose. The agency has a well-structured R&D program that is regularly reviewed by an outside advisory committee.

Although the FHWA research budget looks large, a closer look shows that most of the funds come out of the Highway Trust Fund and are funneled through the States via the Highway Planning and Research (HP&R) Program. State DOTs use HP&R funds primarily for a variety of planning analysis and evaluation projects; a tiny amount of incremental R&D and some demonstration programs also benefit from these funds in some States.

Finally, much more must be done in the area of transportation systems research. R&D expertise is narrowly focused in the modal areas. The FAA R&D program and perhaps SHRP (for highway research) are two efforts that are somewhat more systems-oriented than any others. However, SHRP reflects the concerns about pavement durability of the highway engineers who developed the program, and does not address traffic engineering, construction, or other crucial highway performance issues. A truly strategic program would need to incorporate exactly such items and address intermodal issues as well.

Using Federal Resources Efficiently

Considerable duplication of research into common public works problems exists in Federal agencies. For example, the Corps of Engineers has major pavement test facilities and scale models and computer programs that address water scour and erosion problems of the types that concern FHWA engineers. Under ideal conditions, these could supplement FHWA's much less extensive facilities. However, OTA found that with few exceptions, if an agency such as FHWA requests another entity, such as the Corps, to undertake R&D, the requesting agency ends up dissatisfied, regardless of the quality of the technical expertise and facilities, because its research is given low priority. The requesting agency often finds itself with project results that are late and over budget. **To stretch Federal dollars, Congress could require Federal operating agencies to develop better mechanisms to avoid duplication and to coordinate and carry out cooperative research. Including as part of an agency's formal mission the responsibility to carry out R&D for other agencies is one way to do this. No matter what coordinating method is chosen, ensuring stable funding by the requesting agency for a project is a priority.**

[35]The Safe Drinking Water Act, in Sections 1415 and 1416, allows for such alternatives. David Schnare, Office of Drinking Water, U.S. Environmental Protection Agency, personal communication, July 15, 1990.

APPENDIX

Workshop Participants and Other Reviewers and Contributors

State and Local Infrastructure Management and Financing Workshop, July 7, 1989

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